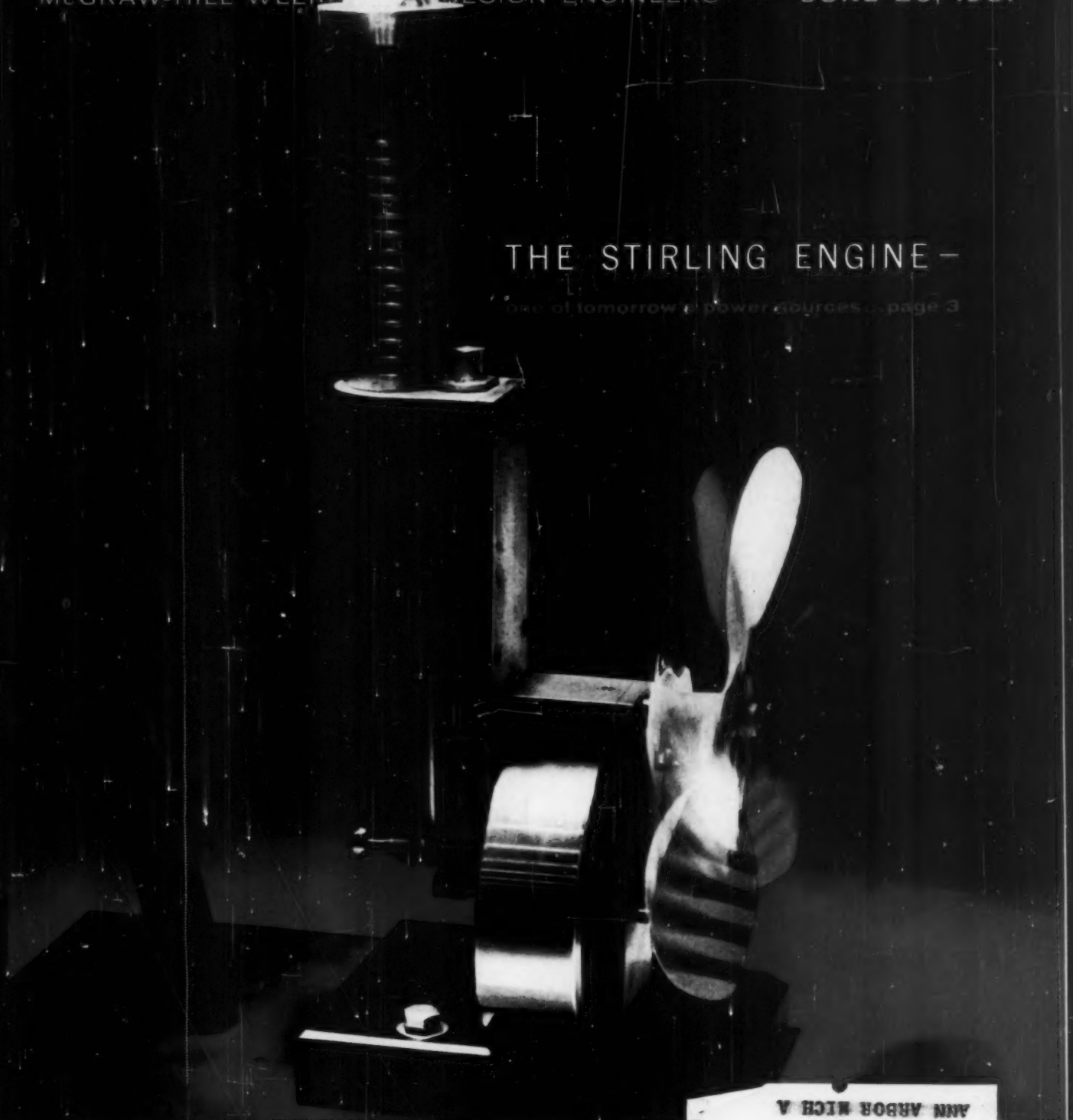
PRODUCT ENGINEERING

McGRAW-HILL WEEKLY FOR DESIGN ENGINEERS · JUNE 26, 1961



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one of tomorrow's power sources ... page 3

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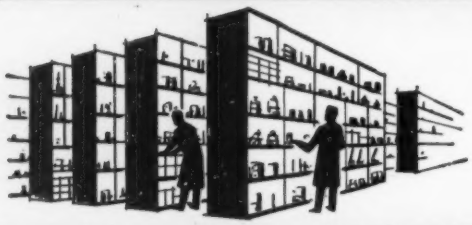
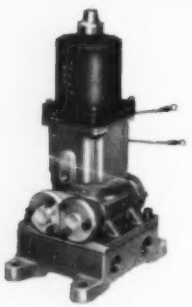


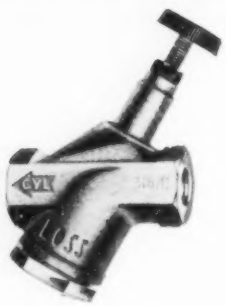
The stock shelves at **Ross** include more different air valves than any other stock shelves in the valve world

Do you know these air controls by Ross?



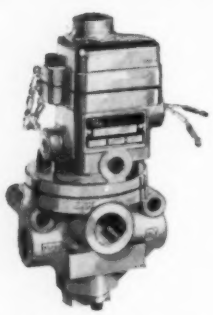
50 Million Cycles in Tests

Ross Goldmodel. A lightning fast, base mounted valve with its solenoid immersed in oil to run cool for long, long life. Full JIC. 3-way, 4-way and 4-way 5 port models. ¼" through 1¼".



Control Cylinder Speed

Speed Control Valve. The adjustment screw directs air through an orifice that's engineered to give fine shadings of control at either high or low flow rates. ¼" through 1¼".



Does a Big Valve's Work

"Headline Series". Highest capacity valve-size for valve-size of any valve we've seen. Use a smaller, economical inline valve to do a bigger, more expensive valve's work. Fast. S-way, 3-way, 4-way. ¼" through 1½".

Especially for Tough Duty

Ross #100 series. Rough, tough jobs call for this valve which can pass most dirt and foreign matter with no trouble. Few moving parts and short poppet travel makes it especially wear resistant.

FOR OTHER ROSS VALVES SEE SWEET'S PRODUCT DESIGN FILE

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PRODUCT ENGINEERING

McGRAW-HILL WEEKLY FOR DESIGN ENGINEERS

June 26, 1961 Vol. 32, No. 26

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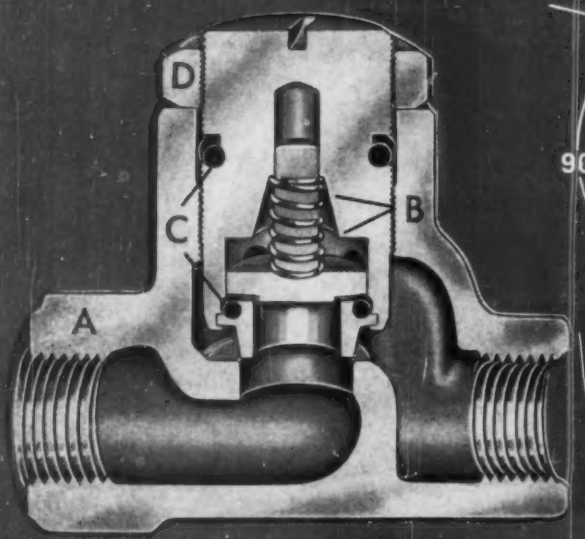
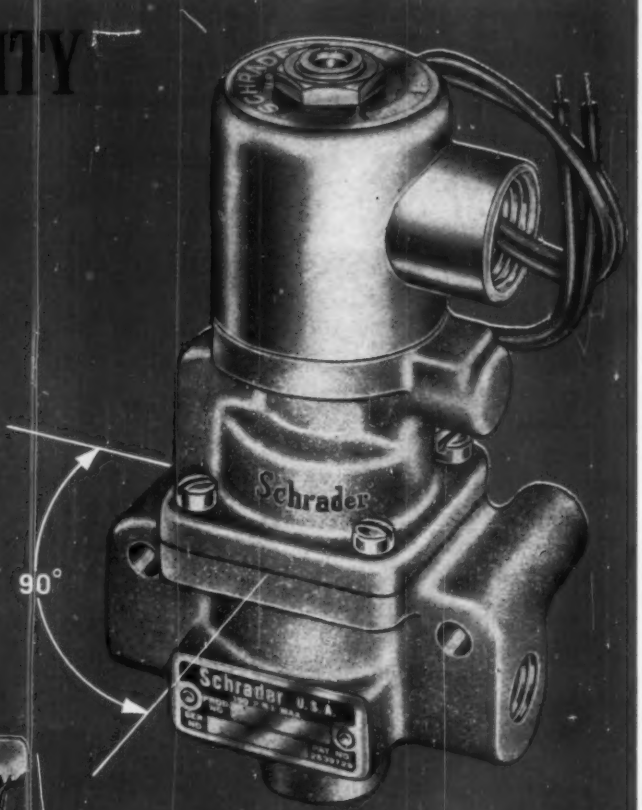
THERE'S A QUALITY DIFFERENCE IN AIR CONTROL COMPONENTS...





...you can see the difference in any Schrader Air Product

FOR EXAMPLE: Schrader Flow Control Valves—a unique combination of a poppet by-pass valve and a large "cone seat" metering valve provides full air flow in one direction and carefully controlled flow in the other. (A) Body of cast brass. (B) Compact plunger assembly replaceable in one unit. (C) "O" ring seal for surest airtight performance. (D) Extra-fine screw thread adjustment for vernier-like setting and sturdy lock-nut to hold adjustment even under rough treatment.

ANOTHER EXAMPLE: Solenoid-operated 3-way Valves by Schrader permit electric control of air power and make possible new versatility and compactness in automation and machine design. Typical feature . . . by shifting pilot chamber head 90° a normally-open type may be changed to normally-closed, and vice versa. This poppet type valve, has a self-cleaning seat and provides full air flow assuring optimum characteristics for cyclic operations. Available in five pipe sizes from ¼" to 1".

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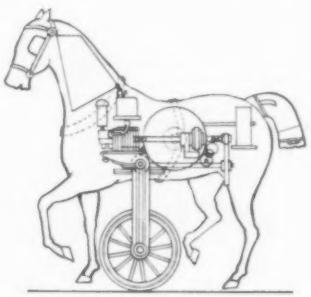
INTERESTING TO NOTE

On our cover--Light focused on a quartz "greenhouse" produces the heat needed to drive this Stirling engine at approximately 100 rpm. This prototype, designed by Battelle Memorial Institute, is one of several novel power sources suggested in the article on page 51. The Stirling engine is about 150 years old, but it wasn't until the German firm of Otto & Langen began manufacturing a new type of internal combustion engine that industrialists took note. In a short time 35,000 of the engines were sold throughout the world and others tried to copy the design. Unfortunately, many of the copies or "improvements" made the same error O & L did—by following steam engine practice to a great extent, they designed gas combustion into slow-speed horizontal engines. This presented difficulties. Some of the early engines tried an electric ignition system but the majority relied on ignition by means of a flame drawn into the cylinder at the proper moment. Too often, the explosion of the gases within the cylinder extinguished the flame. In many cases, two flames were necessary—one to ignite the gaseous mixture; a second to ignite the first after combustion.



In time, engine designers realized that the design of a gasoline engine differed radically from a steam engine. Selling the public was a different matter. That's when, in 1897, an inventor received a patent for a "petrol horse." His invention consisted of a large wooden horse balanced on a single wheel. Within the horse was a gasoline engine to power the wheel. It was the inventor's hope that farmers would simply substitute his "petrol horse" for the real thing. It was built in such a way that it could be easily snapped into harness. Needless to say, the public was cool to the idea.

Cloak and sail

On a windy November day in the year 1844, anyone overlooking the Bay of Biscay could witness a sassy sight. While a squadron of the British Navy lay at anchor, a weird-looking craft sailed right through the fleet—until it finally was picked up by HMS St. Vincent. Close inspection showed the small craft to be a rubber boat, inflated

British Museum

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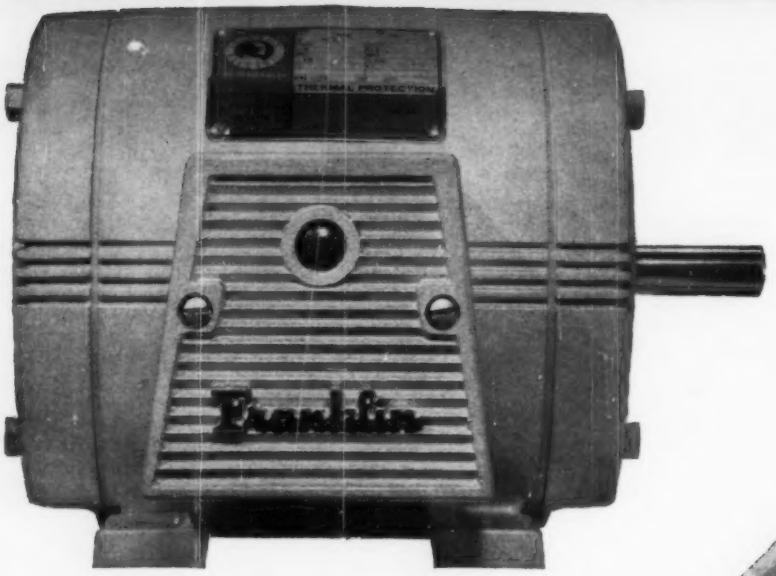
YOU CAN'T SEE THE OVERLOAD PROTECTOR ON THIS POLYPHASE MOTOR



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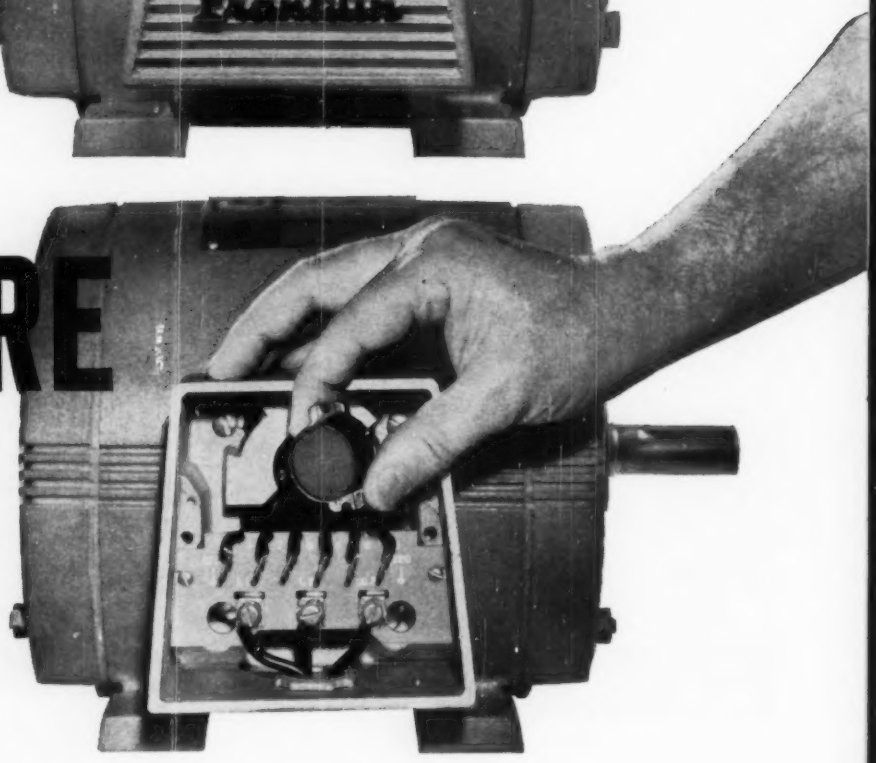
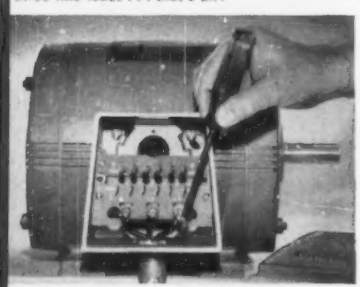


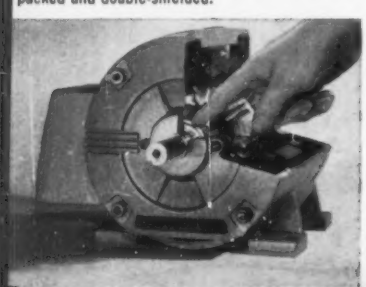
The new Franklin integral is the only polyphase motor (1 to 7½ hp) designed with a built-in space for inherent protective devices. Complete motor protection, even under locked rotor conditions!

Tough yet lightweight aluminum means lower shipping costs, easier assembly line handling, lower production costs.

Comes pre-wired to your specifications. Handiest terminal board design ever—just connect three line leads . . . that's all!



Burly bearing system keeps grease in the bearing for longer motor life. Bearings are prepacked and double-shielded.



FRANKLIN—THE ONLY POLYPHASE MOTOR WITH A BUILT-IN SPACE FOR INHERENT PROTECTOR.

Inside the Franklin conduit box is a common sense idea that every engineer will appreciate. This is the *only* polyphase motor with built-in space for protector devices. Because this one built-in device protects against *all* motor burnout possibilities, even under locked rotor conditions, this new motor can be completely protected at far lower cost than ordinary motors.

The protector comes pre-installed, in exactly the right size to protect the motor under the most adverse conditions. Saves you time *and* money. Another point. The motor's appearance stays streamlined, because protectors stay where they belong —inside. Write for a free color brochure on the new Franklin integral motor.

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with air, and using an umbrella for sail. The boat was the invention of young naval officer Lt Halkett, who hoped the idea "would be made applicable for general purposes in the Naval Service." The Admiralty not only felt otherwise but thought so little of the rubber craft that its cruise through the fleet was not considered important enough to be recorded in the admiral's log. Ironically, in the war that ended a hundred years later, rubber boats were to save the lives of 23,000 Allied airmen.

Halkett's design was most unusual—a cloak that was worn like a blanket. In case of trouble, it could be quickly inflated. The outer cover of the cloak was canvas; the inner layer was a rubber "inner tube." Although the "cloak-boat" was never officially accepted by the British Navy, it did serve as a prototype for rubber boats used in arctic explorations in the 1840s and '50s. After the second World War the English Navy established a committee to study rubber boats; and, after an exhaustive study, found that "rubber aircraft dinghies offer the best prospect of being adapted for ships." Four years later, rubber rafts were officially adopted as standard naval equipment.

The ingredients that go into rubber products today are quite different from those of Halkett's day. The article on p 46 identifies the main ingredients in a rubber compound. —Benedict A Leerburger Jr

SIDELIGHTS

Every so often a release crosses our desk stating that a convict has spent the past 20 years in his cell calculating π to the umpteenth place, or else a new computer has worked out π to several hundred places. It's been sort of like trying to see how many people can fit into a phone booth. The latest contributor is N. D. Robinson, a mathematician at EMI Electronics Ltd's Hayes laboratories. With the aid of a computer he worked π to 10,880 decimal places. The complete operation included 35 million separate calculations and took 13 hours of computing time. In 1873, a Mr. W. Shanks calculated π to 707 decimal places, but it was recently found that he made an error at around the 530th decimal place. Moral: No matter how you slice it, it's still π.

Ode to the engineer

By George Ashton

The most maligned of men, I fear,
Is that character known as an engineer:
And I don't mean the guy who eats up terrain
In the cab of a thundering railroad train.
I speak of the Joe with an ancient Ford
Who's glued to a stool and a drawing board.
With his brilliant mind and skillful hand
He earns his company a hundred grand
And they, most mercenary of men,
Have the nerve to pay him only ten.
The guys in the shop, too, rob him of fame:
When the job goes haywire, his prints get the blame.
The P.A. is firmly convinced he's a nut
And his wife tells him daily he's stuck in a rut.
Between him and the boss there's an impassable gulf
And the gal on the switchboard thinks he's a wolf.
At lunch time when profound topics are aired
Blank stares greet his *E* equals *MC* squared!
And tho he's with Lockheed or Douglas or Hughes
It's always the test pilot who makes the big news.
So this rest-room poet now raises his beer
In a long, silent toast to the poor engineer.

NEXT WEEK IN PRODUCT ENGINEERING

. . . The engineer's bookshelf

An extensive bibliography of technical books for the design engineer. Revised and expanded to include over 500 references in 25 fields.

. . . Mechanical brake with feedback and servo characteristics

Common hand brake is regulated by springs and solenoid to provide constant-torque or constant-tension operation.

. . . Estimate equipment cost with six-tenths factor

If size and cost of one machine are known, nomograph calculates cost of a different size.

. . . The three illnesses of today's R & D

The general public has been oversold, researchers are more concerned with having money than in solving problems, engineers are not making best use of the results.

WHAT'S HAPPENING IN RESEARCH...

More data on pressure effects

Continuing their study of the effects of high hydrostatic pressure on circuit components (*PE—Mar 6, p 6*), C. L. Buchanan and M. Flato of Naval Research Lab now report on magnetic-core materials. Some of the results have been surprising.

With only a moderate increase in pressure (to just about 1000 psig), the inductance of coils wound on 50% nickel-iron cores increases nearly 100%—and then holds almost constant to 10,000 psig. On the other hand, coils wound on 75% nickel-iron cores showed almost no change to 8000 psig and then a slight decrease in inductance.

Coils wound on grain-oriented silicon steel cores also showed a decrease in inductance—about 14%. But these cores were of a different type (split rectangle as opposed to toroidal).

Tests were made at a frequency of 1000 cps, with pressure increases in 1000-psig increments and pressures being applied for relatively short periods. Now, additional tests are planned, using longer test periods and observing the effects of repetitive cycling.

Columbium sounds off in fracture tests

Evidence that columbium, like tin, undergoes a "twinning" reaction, accompanied by audible squeaks that may provide new clues to its stress-strain behavior, was presented to a Navy Science Symposium by E. S. Tankins of Naval Air Material Center.

In tin, the twinning, accompanied by audible clicks, occurs at room temperature (*PE—May 30 '60, p 9*).

In columbium, the phenomenon has thus far been observed only at very low temperature—around −320 F. Significantly, this is also the temperature at which columbium appears to have its highest yield point. However, the relationship needs further exploration and explanations

Rhenium plate for lower cost tryouts

For those who want to try out the "new" metal rhenium, plated coatings may offer a relatively low-cost route.

This metal, though now available commercially, is still close to $600/lb. Rhenium plate, on the other hand, can be deposited in 0.0001-in. thickness at a cost of about 5.3¢/sq in. Technic Inc, which recently introduced plating salts and solutions on a commercial basis points out that rhenium is the highest melting metal that can be plated. It melts at 5732 F, and has electrical properties (low arc erosion, stable contract resistance) which recommend it for such applications as sealed relays. Hardness is over 300 Vickers DPH; specific resistance, 19 x 10^{-6} ohm-cm.

Plating salts, in quantity, are $1/gm; prepared solutions, $20/liter.

(Note: for more on rhenium's prospects and properties, see *PE—Mar 17 '58, p 66.*) **—ARG**

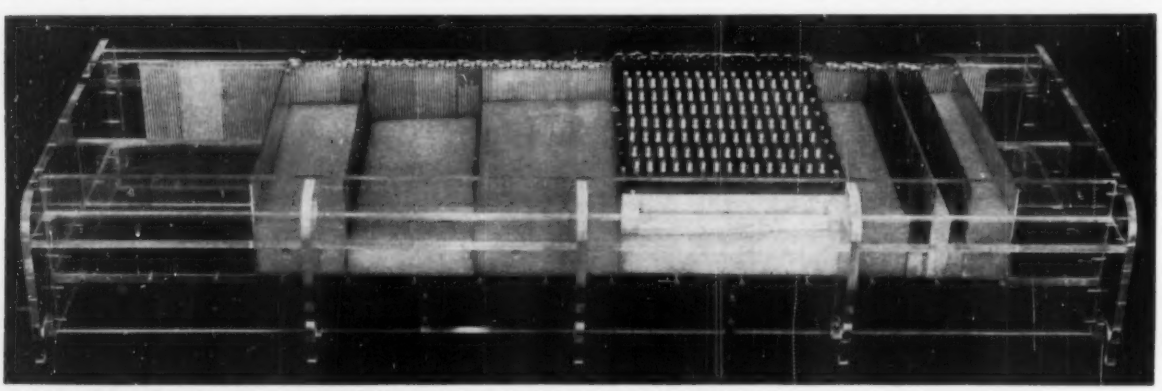
Electrolytic analog for transformer research

A system in which a capacitive network represents turns in a transformer winding, and the resistance in the electrolyte is inversely proportional to transformer capacitance, has been developed by Bruce Peebles & Co Ltd, Edinburgh, Scotland.

The aim: to determine initial distribution of an impulse or surge voltage applied to a transformer winding.

Peebles points out that, for a very short interval of time immediately following a surge, a transformer winding may be represented by a purely capactive network, the nodes of the network being the turns of the winding, and the capacitances between nodes being those between adjacent turns, both radially and axially. Thus, an analogy can be drawn between capacitance in the actual transformer and resistance in the model.

Surge is simulated by applying a potential between the line conductor and the grounded neutral, and intermediate conductors then attain a potential between these limits that approximates the resistance distribution between conductors. These potentials are measured by a voltage divider connected between line and neutral, with a detector between the conductor under test and the divider's sliding contact. The divider is made self- balancing by using a closed loop servo system and the conductor potentials are indicated on a decade counter, showing them as a percentage of the potential applied to the line conductor.



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DEVELOPMENTS TO WATCH...

Tolerances in millionths on a production basis

Hydrostatic spindle bearings and new slide-control mechanisms are making it possible to hold grinding tolerances to 0.000,010 in, says H. S. Sizer, director of design, Brown & Sharpe.

Headstocks are now available for attachment to late-model machines which will hold at least 0.000,015 in. With new linkage mechanisms that control work-wheel center distance within 0.000,075 in, a diametral tolerance of 10 millionths can be applied. This, as Sizer proudly pointed out to the ASTE, is a substantial improvement over the best production grinding of cylindrical parts less than 10 years ago. At that time, he set 25 millionths as the practical limit.

The spindle itself, supported on 4 pockets or pads of oil, shows an axial oscillation of little more than 0.000,005 in., so out-of-roundness can be held to less than 0.000,010 in., permitting the 10-millionths dimensional accuracy.

Spray-cast coating offers low-cost cylinder protection

A coating process that combines metal spraying and die-casting in an unusual way is being readied for commercial application late this year. It's specifically designed to provide a wear-resistant coating for the bore of die-cast aluminum cylinders and its first use will be on small aircooled portable engines. But it should have other possibilities in mass-produced equipment. National Lead Co, which developed it, says it's less expensive than chrome plating or molybdenum spray-bonding and it eliminates many of the problems of pressed-in ferrous linings.

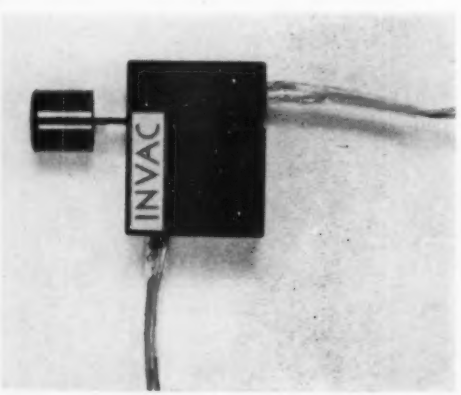
Instead of placing a ferrous surface directly on the cylinder after it is cast, the coating is sprayed on the core of the casting die. As the casting solidifies, it shrinks around the core and grips the sprayed coating. This "transplant" process, says A. F. Bauer of National Lead, "creates a taper-free bore of extremely high smoothness and outstanding accuracy." A tolerance of 0.003 in. has been held on cylinders 3¼ in. dia., using a coating 0.020 in. thick.

Among the advantages of the process, Bauer claims, is the fact that the cylinder bore does not have to be machined to close tolerances or honed. He notes, however, that the process is not suitable for small runs. Relatively expensive tooling, a die-casting die and several cores are necessary to produce even a few prototypes of any transplant-coated part.

Contactless switch nears commercial introduction

A miniature lamp and a photocell are combined in a new contactless switch designed by Invac Corp, East Natick, Mass. It's less than 1 by 1¼ by ¾ in.; and because it has no metal contacts, should have an almost infinite life. There is, of course, no contact "bounce" and it operates with zero "misses." Furthermore, says Stanley Plaisance, vp-engineering, the low impedance of the photocell makes it particularly attractive for use with transistorized circuits.

Invac is now putting the unit into production for its own use (in data-processing keyboards), expects to be able to market the component commercially in about 6 months. Four basic types are planned—normally open, normally closed, break-before-make, and multiple combinations. Plaisance says it will be comparable in cost to mechanical-contact switches now used.



PHOTOELECTRIC SWITCH contains miniature lamp and photocell, with shutter between them. When button is depressed, light beam is cut off. Resulting resistive change in the photocell is the output signal.

Portable frequency meter designed by Navy

A precision frequency meter that will also serve as a signal generator has been designed at Naval Research Lab. It can be used as a highly accurate, direct-reading decade signal source for driving other equipment, too, NRL says. The prototype weighs 43 lb and covers the frequency range 0 to 1 mc, with an accuracy of 1 ppm; but this can be extended to 1000 mc and accuracy can be increased simply by increasing the accuracy of the reference standard.

A report (NRL 5604) is now being prepared outlining the unusual design features of the instrument (Navy says it "corrects all major deficiencies of existing equipment") and is to be made available through OTS as PB 154 684 in about a month.

New ceramic decals to mark instrument dials, glass cylinders

Ceramic decals for placing scales on graduated cylinders and instrument dials are being produced by a new photographic technique, developed in Canada and now being introduced in the US. Though the technique is "photographic," a camera is not used. The photopositive is produced by direct contact with a micrometer-controlled positioning device, working directly from the blueprint. The decals can be made in color and fired onto glass; and, says Cecil H. Jacobs, Decalcraft USA, Hatfield, Penna, developer of the process, graduations are accurately reproducable from 0.005 in. up. Price is expected to be competitive with other marking systems; and orders for as few as 50 will be accepted.

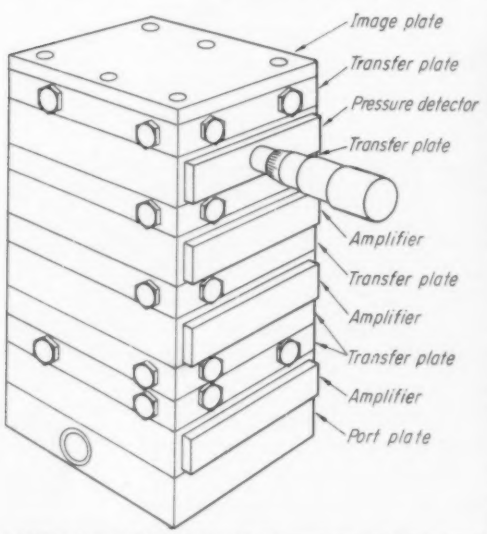
Fluid-power "building blocks" give flexibility to control systems

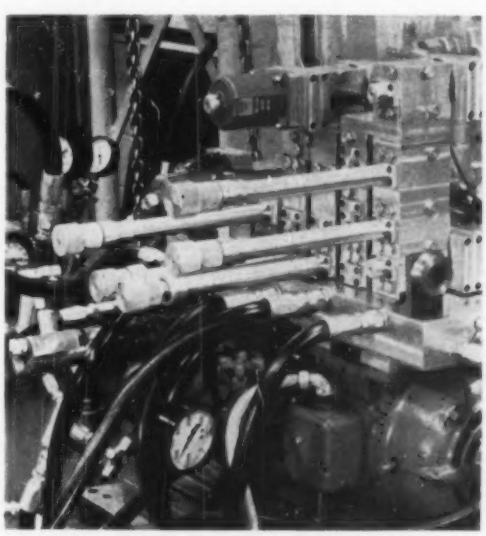
A modular system that permits the packaging of complete fluid-power circuits by stacking valve sections and manifolding is being developed at Racine Hydraulics.

Its basic unit is a balanced, two-way spool valve which serves as an amplifier. Stacked with either a "flow detector" or "pressure detector" module, it becomes a two-stage valve, and additional units will make larger modules like the 4-stage valving shown here. In this system, one spool valve serves as the power stage, another is a preamplifier and a third is a shielding amplifier. The fourth stage is a detector section.

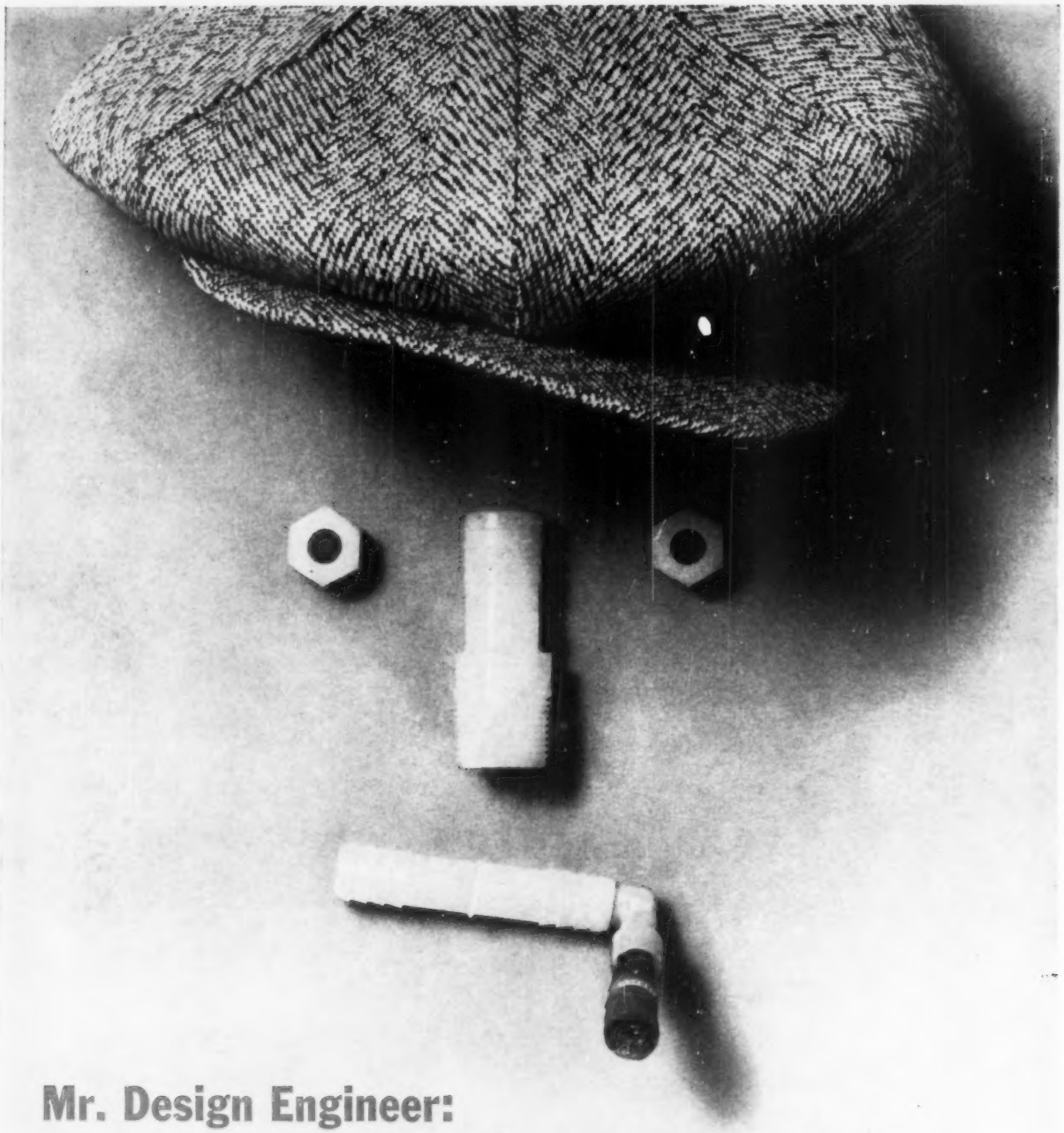
The detector is inserted in the system to minimize errors in controlled speed in force. It senses variation in flow or pressure and applies a proportional pressure across the shielding amplifier spool. This reduces the effect of gradient locking and variable-spring-rate force on the preamplifier; and this, in turn, modulates the main power spool, which controls system pressure or flow.

Russ Henske, Racine director of research, says a complete machine tool system, combining 4 four-stage systems, with 2 flow controls and 2 pressure-reducing valves, can be packaged in a unit no more than 18 by 18 by 12 in., with no external piping except from stacks to cylinders and pressure inlet, and return to tank. **—ARG**





4-STAGE POWER CONTROL system is diagramed and pictured here. Note how system is built up from a series of amplifier blocks.



Mr. Design Engineer:

Here's toughness in all shapes and sizes...

Plaskon® Nylon is always ready when there's a tough job to be done! Rough handling and abuse in both installation and use prove the high impact and tensile strength of pipe fittings molded from Plaskon Nylon. Their corrosion resistance is superior to that of most metals; cost is often much lower.

Now available in sizes up to 4 inches, the insert-type fittings shown above are molded of tough Plaskon Nylon. N.S.F. approved, they are used in jet well installations, industrial piping, air conditioning, and watering systems for livestock, golf courses, lawns, and ice-skating rinks.

Plaskon Nylon injection molding compounds also offer less shrinkage and better dimensional control for precision parts such as gears and bearings. Parts mold easily because Plaskon Nylon doesn't "drool" and has a broader melting range. Call or write for full performance data, and for expert help with any molding problem.

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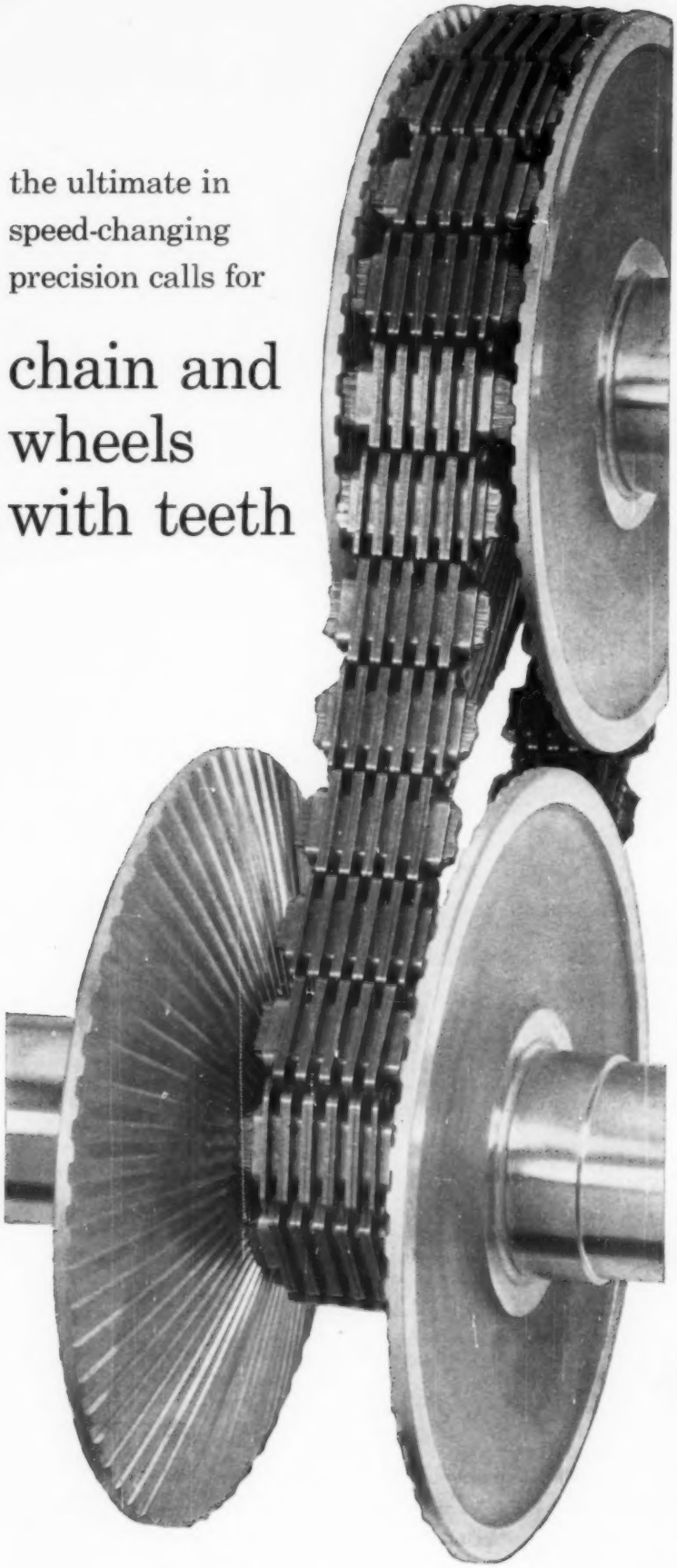
BASIC TO AMERICA'S PROGRESS

the ultimate in speed-changing precision calls for

chain and wheels with teeth



LINK-BELT P.I.V.

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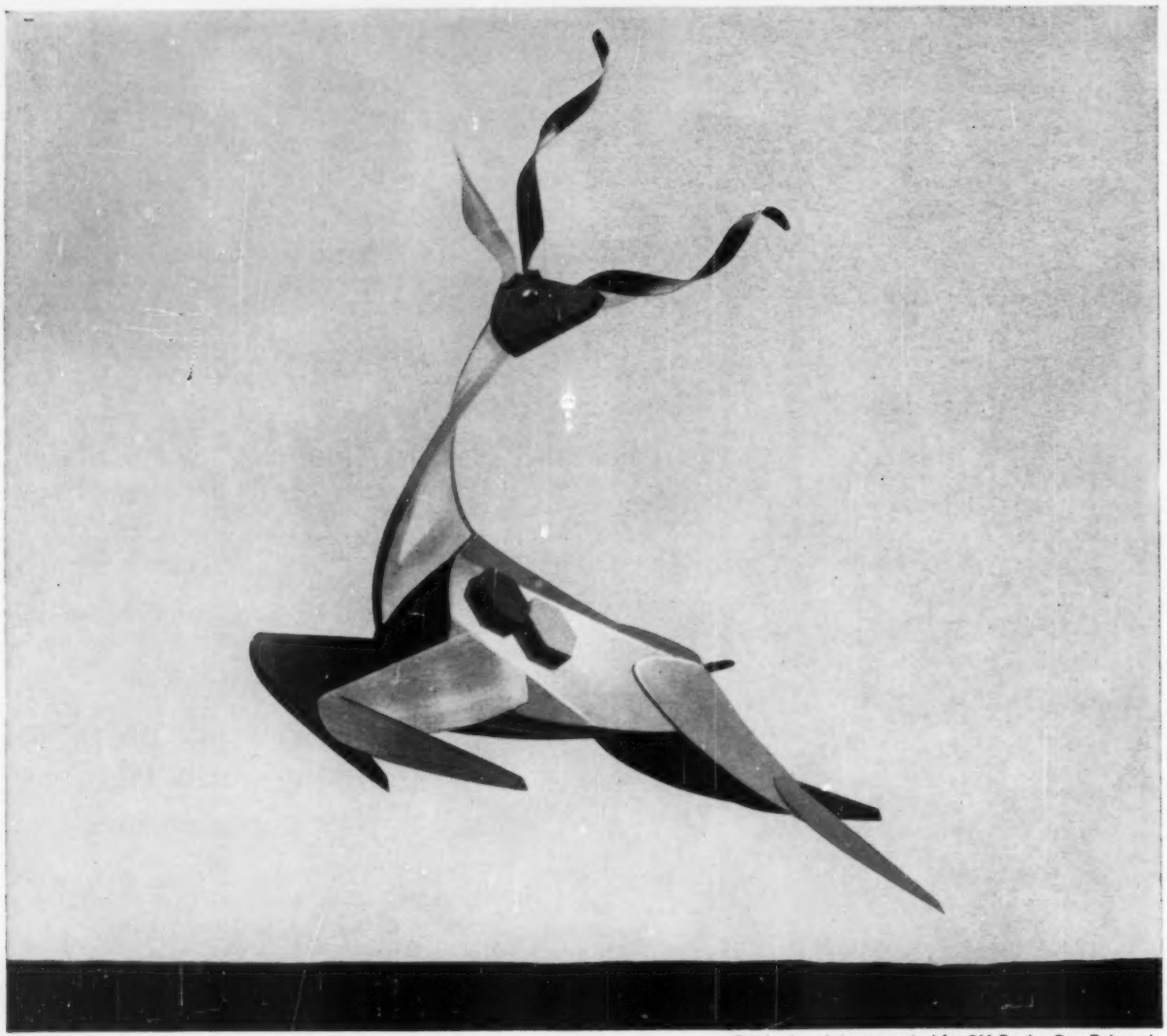

Original sculpture created for 3M Co. by Guy Palazzola

Freedom

. . . New design concepts "take off" with 3M Brand Adhesive Products!

Want to escape design limitations imposed by old-fashioned fastening ways? Help yourself to new elbowroom with the modern, clean-lined, functional fastening you get with 3M Adhesives!

New simplicity! Using 3M Adhesives for assembly, you eliminate fasteners, nuts, bolts, rivets, staples. Fewer parts give you simpler construction that costs less, looks better. The making of necessarily complex shapes and castings, too, is simplified by 3M Adhesives; you break down the complex part into several simple sections, then adhesive-bond into one.

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"SCOTCH-WELD" is a Reg. T.M. of 3M Co. ©3M Co., 1961

What do you want to bond to what?

The 3M Gazelle is fabricated of these materials and bonded with 3M Adhesives, including SCOTCH-WELD® Brand Structural Adhesives:

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ADHESIVES, COATINGS AND SEALERS DIVISION

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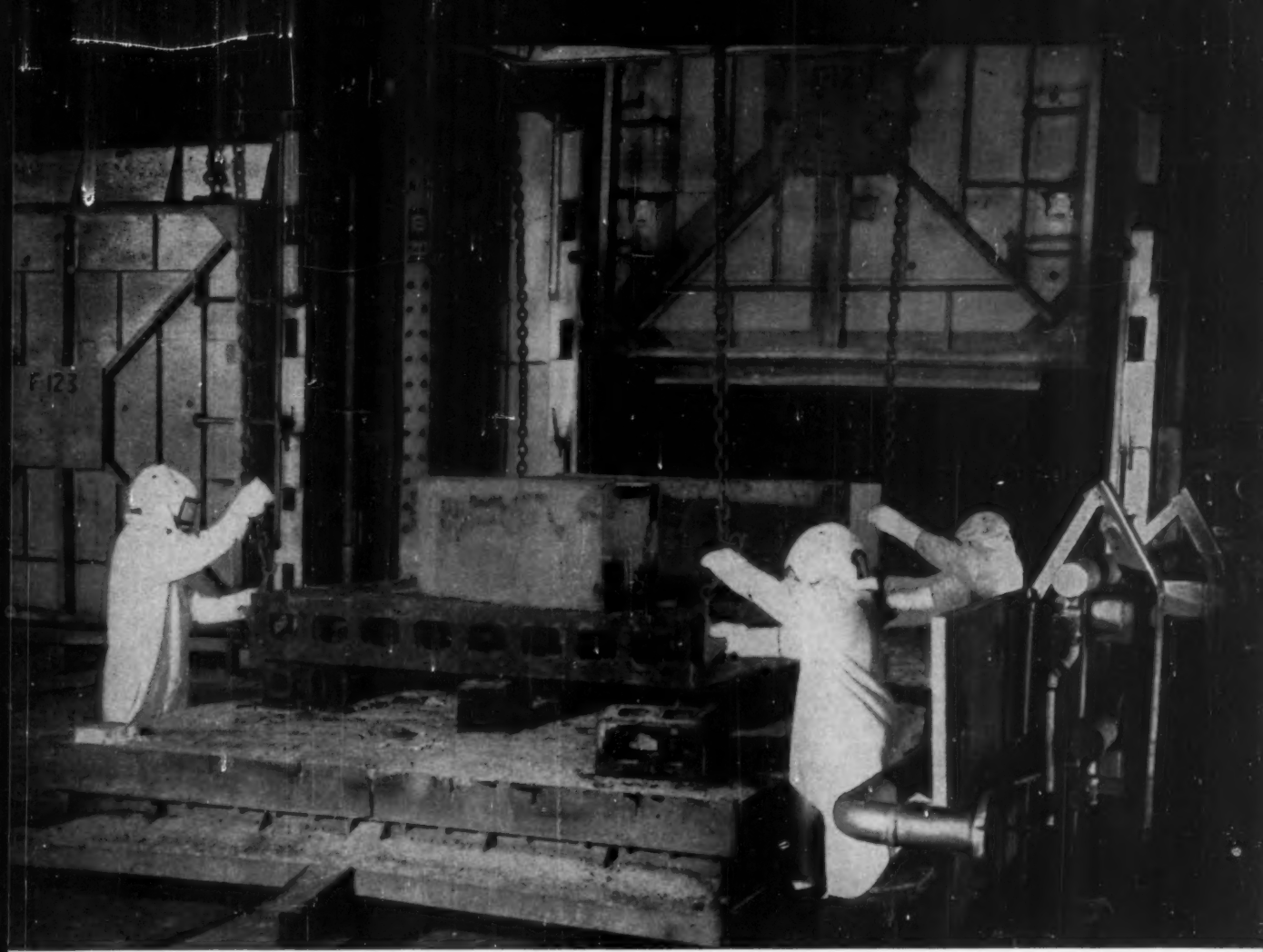
. . . WHERE RESEARCH IS THE KEY TO TOMORROW

3M COMPANY



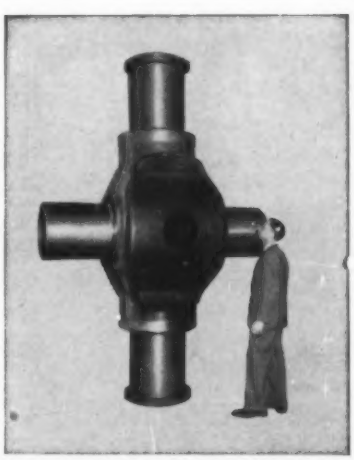
Blaw-Knox Steel Foundries have the heat treating capacity to handle the largest casting

Your steel casting gets precisely the characteristics of uniform hardness, toughness, or temper you specify in a Blaw-Knox Steel Foundry. Blaw-Knox Steel Foundries are equipped with huge pit-type furnaces—some as large as 42 feet × 20 feet × 13 feet deep, and banks of car type furnaces to accommodate the largest steel casting or batches of smaller ones.

Quench tanks as large as 21 feet × 12 feet and 8 feet deep are available, and all Blaw-Knox Steel Foundries are equipped for spray quenching in which specific areas of steel castings are given special quenching. Further flame hardening or other hardening procedures are provided to meet your exact requirements.

Complete heat treating, quenching, and hardening is another way in which Blaw-Knox Steel Casting Service adds value to your product. Blaw-Knox, as one of the world's leading rolling mill and industrial machinery builders, keeps a sharp eye on the end-use requirements of a casting from start to finish. It's your assurance of a component of the highest quality, made for maximum service.

If you design or build products using cast steel components, ranging from 50 pounds to 300,000 pounds, Blaw-Knox would like you to have a copy of our brochure detailing Blaw-Knox Steel Castings Service. Write to the Foundry and Mill Machinery Division, 300 Sixth Avenue, Pittsburgh 22, Pennsylvania. No obligation of course.



This main axle casting for the 60-cubic yard Mountaineer Shovel was cast in a Blaw-Knox Steel Foundry. Wt.—18,000 lbs.

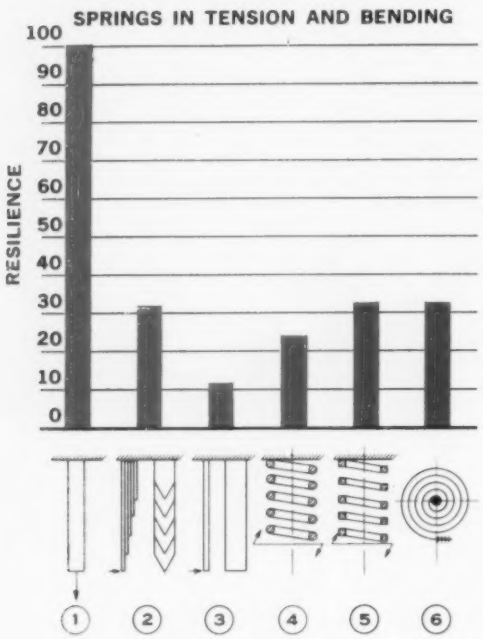
BLAW-KNOX

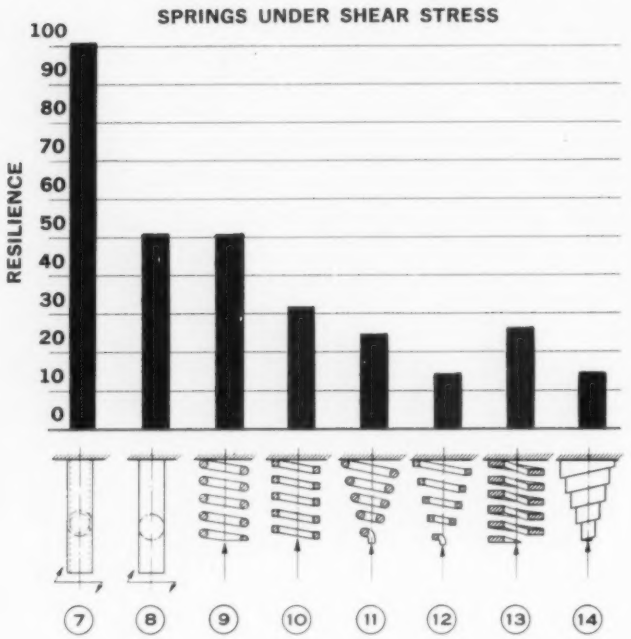
Steel Castings

CIRCLE 13 ON READER SERVICE CARD

What Type of Spring to use ?

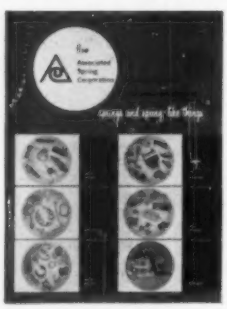
Here's a quick comparison of relative efficiencies





1. Simple flat spring
2. Leaf spring
3. Rectangular flat spring
4. Round wire compression spring
5. Square wire compression spring
6. Flat wire spiral spring
7. Thin wall tube
8. Solid rod
9. Round wire spring
10. Square wire spring
11. Round wire conical spring
12. Square wire conical spring
13. Rectangular wire spring
14. Volute spring

Relative efficiency of various types of springs can be compared on the basis of energy-absorbing capacity per cubic inch or per pound of metal in the active portion of the spring. For theoretical purposes the simplest forms—wire in tension (1) and thin-wall tube in torsion (7)—represent the ultimate, since all their fibres are stressed alike. The comparisons shown above assume springs are of metal of equal quality, able to withstand the same fibre stress. Obviously, other considerations may affect spring selection such as space available, material desired, atmospheric conditions, manufacturing cost, etc. So efficiency is often tempered by expediency.



If you're embarking on a project requiring springs, tap the knowledge and years of experience available from Associated Spring and its divisions. *Write for "How A.S.C. Solves Design and Production Problems of Springs and Spring-Like Things."*

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THE ENGINEERING WEEK

AMBITIOUS MUSCRAT can propel itself in protected waters at 3 mph, then drive off over highways at 60 mph. Fully loaded it can climb grades in excess of 60%, says its developer, American Motors. The ¾ ton vehicle has an aluminum engine mounted inboard on the right of the driver. It is of continuous-skin design.

GAMA-GOAT hinges in middle for maneuverability, gets buoyancy from hull-like construction; has a 4 wheel tractor unit and a 2-wheel rear body—all 6 wheels are powered. Front wheels and those on rear body are steerable, giving a 20-ft turning radius. Developed by Chance Vought, it is claimed capable of 50 mph on land and 5 mph in water.

They float—new trucks run gamut of design ideas

DETROIT—A new series of amphibious trucks, ranging in size from the ¼-ton "jeep" to mammoth 16-ton carriers, is under investigation by engineers at Detroit's Ordnance Tank Automotive Command (OTAC).

These trucks differ from each other and from their predecessors in several ways, but have this in common—they are designed to float, fully loaded. Some are also light enough to be parachuted or transported by sling under a helicopter.

But whether the truck is sped to its destination by air or more conventional means, it's expected to handle practically any terrain, in any temperature. And, if an inland body of water requires swimming, the truck is expected simply to get into the water, cross it, and get out—all, preferably, under its own power.

Practically all manufacturers of land vehicles, from the strictly automotive companies to White's Reo Div, Caterpillar, and LeTourneau-Westinghouse are designing and producing prototypes under Army development contracts. In addition, at least one aircraft company, Chance-Vought, has developed a vehicle without an Army contract, and OTAC itself may try minor redesigns of existing vehicles. One company, Whirlpool, has produced a body of its own design, on which OTAC has mounted its own power train.

For navigating small inland waters, four approaches are being tried:

- The truck is built, in one design, like a small barge, with outboard wheels. The underbody and sides form a continuous watertight skin which extends higher in front to protect the engine. If a tailgate is used, the closure is made leakproof by a seal. The engine is inboard, sometimes mounted alongside the driver.
- Sealed air chambers are added to a truck of substantially standard design at a number of points. Because

SEALED FLOATING CHAMBERS above wheels keep this arsenal-built truck afloat. High position of chambers gives greater stability. *US Army photo*

ALUMINUM SKINS over aluminum-foil cores comprise the honeycomb panels bonded together to form this Whirlpool-designed truck body. *US Army photo*

the buoyancy that can be provided this way is limited, cargo space is also sealed to act as an additional flotation chamber. In one instance a sump pump is installed in the body to prevent flooding from seal leakage or holes caused by small-arms fire.

• Polyurethane foam replaces large sealed air chambers of a fundamentally conventional truck design. This is foamed in place at strategic locations, and, its proponents point out, is not critically affected by small-arms fire, which would destroy only a limited number of the foam's many closed cells.

• A unitized body-frame structure made up of honeycomb panels is bonded together with resin. In this design by Whirlpool, means for attaching the power train are integral with the body, either incorporated in or bonded to the original honeycomb panels. Some polyurethane foam is also used to increase and equalize buoyancy. OTAC engineers confirm Whirpool's claim that this truck, complete with power train, weighs less than the cargo it is designed to carry (2½ tons).

American Motors' vehicle, the Muscrat, is only 82 in. wide and 148 in. long (a full inch shorter than the company's smallest car, the Metropolitan) and weighs 5780 lb. It can transport two men and 1500-lb cargo over rough terrain.

Its body is entirely aluminum; so is much of the engine block, castings for brake drums, transmission case, transfer case and front and rear axles. The vehicle is powered by the Rambler's standard 127-hp die-cast aluminum engine.

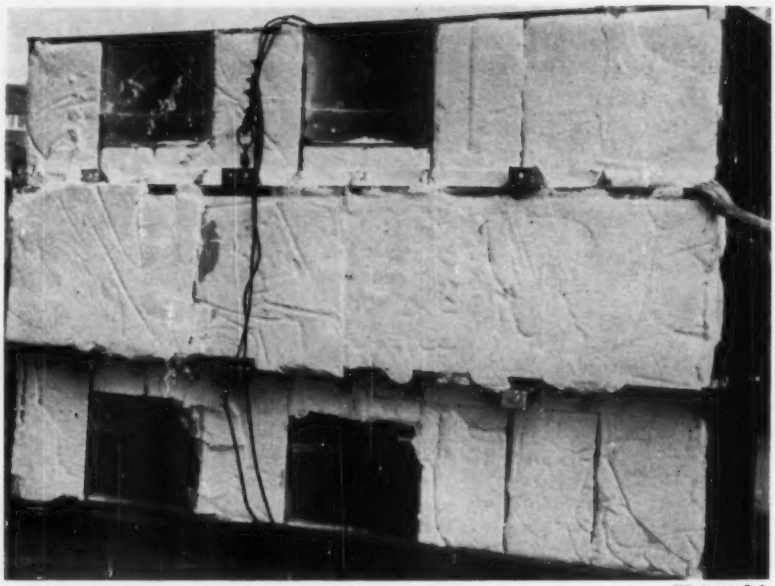
Suspension system is independent for all 4 wheels, and a 4-speed synchromesh transfer case provides for either 2- or 4-wheel drive. Front and rear drive units are split, so differential assemblies can be mounted to the body from inside the vehicle. Axle tubes and shafts are installed and secured from outside.

All trucks tested so far get water propulsion from cavitational action of the spinning wheels. Speeds achieved are around 2 mph. The Whirlpool body allows attaching a propeller driven from an engine power takeoff. This would probably give the vehicle higher water speed.

OTAC points out that all these designs are experimental—for evaluation and investigation of other problems that might arise.

Probably most important, according to OTAC engineers, is stability in water. A stability investigation on one lightweight model has been conducted at the Stevens Institute of Technology Davidson Laboratory. In one test, the truck, loaded to its rated capacity with a 40 lb/cu ft cargo density, has only small static stability. If the vehicle is loaded off-center some 4 in., the resulting heel angle would be 14°. This would not permit a man to walk on the low side of the vehicle, or allow a wave-induced roll of an additional 8° before the vehicle overturns. A load of lighter density would further aggravate the condition.

—Felix Giordano, Regional Editor



US Army photo

FOAMED-IN-PLACE POLYURETHANE fills Reo-built truck underbody cavities with buoyant material claimed practically impervious to small-arms fire.

Engineers, government join to spur Detroit growth

DETROIT—What is called the "world's largest scientific and engineering technical advisory group" has been formed here by the Engineering Society of Detroit and the US Dept of Commerce. The joint group will review some 200 to 600 US government research reports monthly, then urge appropriate local firms to develop some of the products and processes described in the reports.

It's hoped the reports may also lead to establishment of new industrial plants in the area. Should this occur, some of the skilled labor displaced by automation in the last few years may be absorbed.

Government agencies concerned with R & D have long deplored the lag between publication and utilization of research reports. The new committee hopes to cut this lag, and bring more rapid modernization and increased efficiency to local industry. ■

OEEC seminar calls for documentation center

PARIS—The first International Documentation Center for Research Management may be set up by the Organization for European Economic Cooperation (OEEC) as a part of its program to get more mileage out of expenditures by member countries on public and private research.

Creation of such a center was the leading recommendation made at a recent OEEC seminar on research administration, held in Strobl, Austria. Other recommendations urged OEEC to organize international-exchange visits of experts in research management, and meetings to discuss promotion, finance and tax problems connected with research.

The seminar was part of the organization's applied-research program, aimed at developing the scientific resources of member countries and encouraging rational use of existing research facilities. ■

Explosive forming causes only slight stresses

Los Angeles—A myth that has grown with the technology of explosive forming was exploded here by Erik K. Henriksen, senior project engineer of Aerojet-General. Speaking before a session of the ASME Summer Conference, he conceded that explosive forming causes springback and residual stresses—the notion that "the metal moves so fast it doesn't know what's happening to it" is untrue, he said.

But though both springback and residual stresses do occur, Henriksen said, they are much less than those developed by conventional forming methods. Harmful residual stresses, he explained, are usually so slight that stress relief is seldom needed after explosive forming.

To calculate stress in parts, he placed scribed points on parts made from SAE 1020 and 4335 steels that were formed into domes by explosive forming. The distance between the points was then measured before and after forming and the distribution of stresses in an initially formed dome was developed from a set of principal strain curves.

Louis Zernow, director of research for the Ordnance Div. and Irving Lieberman, of the explosives application dept of Aerojet-General, went on to explain the extension of stress calculation to fabrication of refractory metals, compacting parts from powders, welding and other metalworking processes. Some of the latest forming applications, they said, have been developed to produce asymmetrical shapes not possible with hot spinning. Diametral tolerances of ±0.010 in. present no difficulty, even on large parts, and tolerances of ±0.005 in. on formed material thicknesses are common.

MAN-MACHINE SYSTEMS MISUSE MEN

At another session, the man-machine systems, now widely adopted by industry, were evaluated by a social scientist and found wanting. A basic problem, said Dr Nehemiah Jordan of the RAND Corp, is that "man's task is being made too easy." Man is best in any system where he must exercise judgment and control over the process.

Jordan explained that men are flexible, and cannot be depended upon to perform inflexibly. Hence, the man-machine system must be carefully designed to use the full ability of both.

To do this, he said, new guidelines should be devised. Machines must be broken into two categories: tools and production units. A tool is used with man to make a job easier or even possible. A production machine serves where environment is predictable and man is only needed as a backup.

The best combination, said Jordan, is where motivation for man to do a good job is inherent in the task and where his efficiency, thought processes and responsibility are constantly challenged. Man will rebel against any machine system where a challenge is not inherent in the task.

—R E Abbott

Buildings to be electrified by their own gas-fueled engines

Chicago—Several small turbo-shaft engines will generate all electricity, heating, and cooling power for two new office buildings planned here by Northern Illinois Gas Company. According to NI-Gas, the only wires entering these buildings will be telephone lines.

The turbines will burn natural gas taken directly from the company's own pipelines. Shaft power will drive 400-cycle, 3-phase, 270-v alternators; NI-Gas chose high frequency to eliminate all ballast requirements for fluorescent lighting. Exhaust heat will generate steam for heating and absorption cooling. All told, over 55% of fuel energy input will be converted into useful energy though actual efficiency will vary with the seasons. (A similar system has electrified the Park Plaza Shopping Center in Little Rock, Ark for some months now, but it generates at 60 cps.)

The first building, to be ready in July 1962, will have generating capacity of 200 kw from two turbines of 300 shaft hp each. The second (and larger) will be completed in Jan 1963. It will have 800-kw generating capacity, divided between four 300-kw or five 200-kw alternators. Its turbines will generate 300 to 400 shp.

Hot gas will pass through an expansion nozzle to reduce its velocity, then through a conventional tube-type boiler operating at 12 psi. Exhaust gas, cold and relatively slow moving, will be vented directly to the atmosphere. To handle objectionable noise generated at the turbine air intake, NI-Gas will use a right-angle air intake, directing noise straight upward.

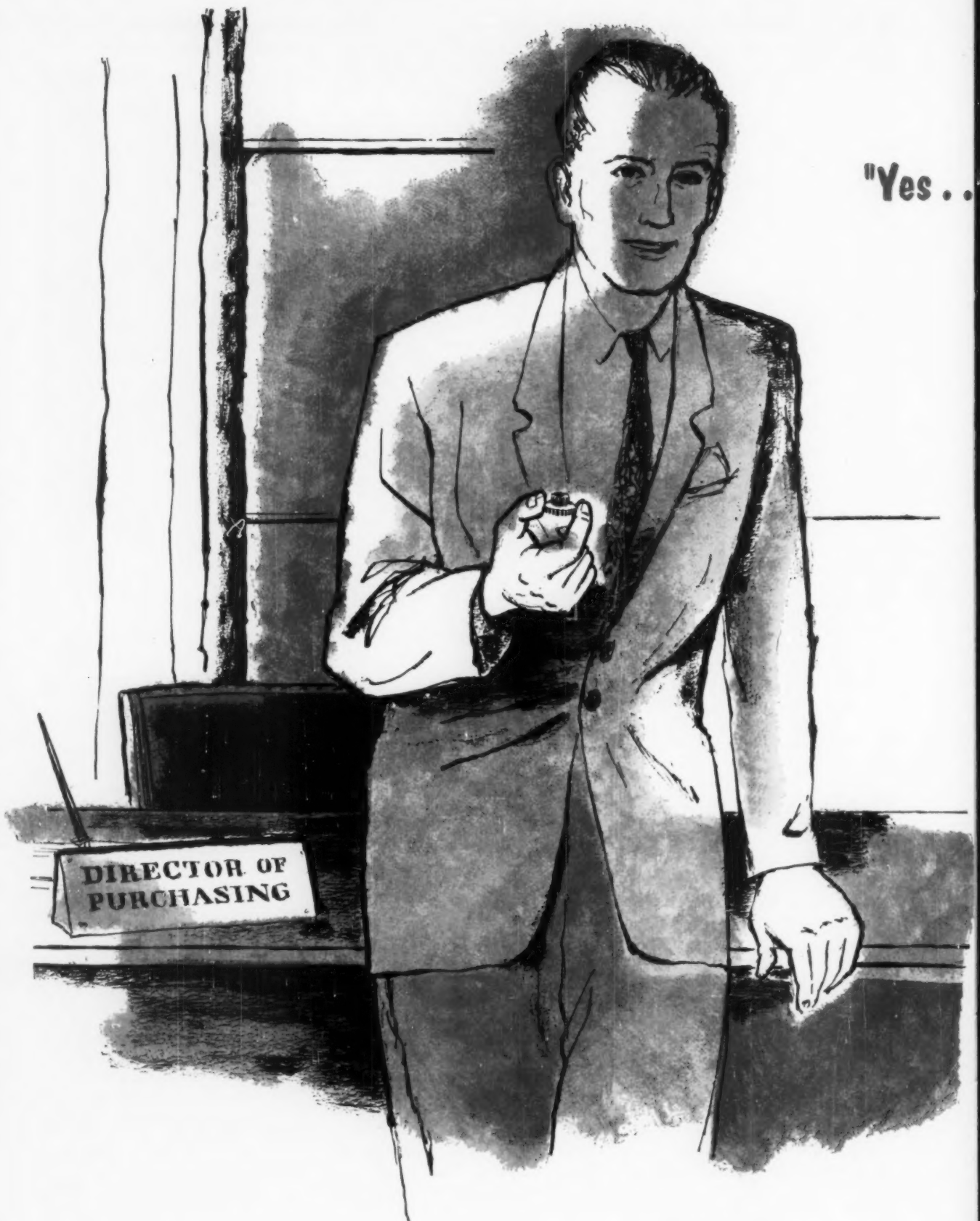
One major problem remaining is operating several turbines in parallel, so that electricity is in phase. So far, NI-Gas has not stated how this problem will be solved. Many office machines and clocks require 60-cycle power; this will be supplied by a separate motor-generator set.

Bruce Cross, Chicago Bureau

(news continued on page 20)

Computer program speedily gives complex shapes

Punched tapes for numerically controlled machine tools can be prepared in a hurry with the Autoprompt computer program now available from IBM. A few English-like words, fed to the computer, are sufficient to specify shapes like the one above. This is in contrast to present methods in which each cut of the machine must be individually programmed. To machine a complex helicopter gearbox cover, for example, the computer was fed 180 one-line statements composed from information on the blueprint. The Autoprompt program then converted this to more than 8000 tool-path instructions, which were subsequently punched into tape for the numerically controlled milling machine. Autoprompt is available free to users of IBM 704, 709 and 7090 computers. And for machine-tool owners who lack computer facilities, tapes can be prepared by one of the many computer service centers spotted around the country.


"Yes . .
DIRECTOR OF
PURCHASING

. . We depend on G.S. for our Precision Gearing!"

"It's just a matter of logic—and good business. You see, we produce rather complex mechanisms. They have to hold up under all kinds of tough conditions in the field. And since Precision Gearing is at the heart of our units, that's the one place we have to *know* that the quality and accuracy of components are consistently right.

"G.S. produces our Gearing to close-tolerance specifications—and we've found that their respect for max. and min. is, if anything, even greater than our own. They deliver our Gearing the *same* from run to run, which keeps our production line moving right along—we don't have slow-downs because of Gearing variations. And failure in the field from Gear trouble is almost unheard of; that means a lot in customer satisfaction, not to mention saving servicing or replacement expense.

"Speaking of money, we've found that G.S. keeps us competitive on costs in the broadest sense. They have the equipment, and the experience, to do precision jobs like ours on a production basis—we aren't paying on the "hand-made" scale. Besides, they make *all* the kinds of Gears and Gearing we need—Spurs, Spirals, Bevels, Helicals, Internals, Zerols, Clusters, Ratchets, Splines, Hobbing, Worm Gearing. That simplifies our specifying and buying—and that's worth money, too.

"Just one more thing. When we do have a special or unusual problem about Gearing, either in production or in development of new projects, we've found that G.S. is as close as our phone. We've had their experts in from their factory several times, and their broad, practical experience has been mighty helpful. It's like having extra specialists right on our own staff!

"Yes, *we* depend on G.S. for our Precision Gearing. Why don't *you* talk to them about your Gear problems?"

YOU'LL FIND G.S. GEARING IN TOP QUALITY PRODUCTS LIKE THESE . . .

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Magnetic tapes record the vibrations of rotating parts

PARIS—Magnetic recording tapes are being used here to make high-precision measurements of vibrations occurring in crankshafts and similar rotating components under dynamic conditions. This method, developed by the French Union Technique de l'Automobile, du Motocycle et du Cycle (UTAC), measures torsion angle to an accuracy of 0.01°. It also identifies natural frequency and critical speeds of the shafts.

Such readings are obtained by comparing pulses picked up from magnetic tapes bonded at each end of the shaft. The tape is cemented to the rim of a nonmagnetic metal disk fixed to the shaft. A magnetic recording head is mounted near each of the two tape disks. With no load on the shaft, pulses are simultaneously recorded on the two tapes. Then the shaft is rotated under load, and the phase difference between pulses is proportional to the torsion angle of the shaft and independent of its speed.

TESTING COMBUSTION ENGINES

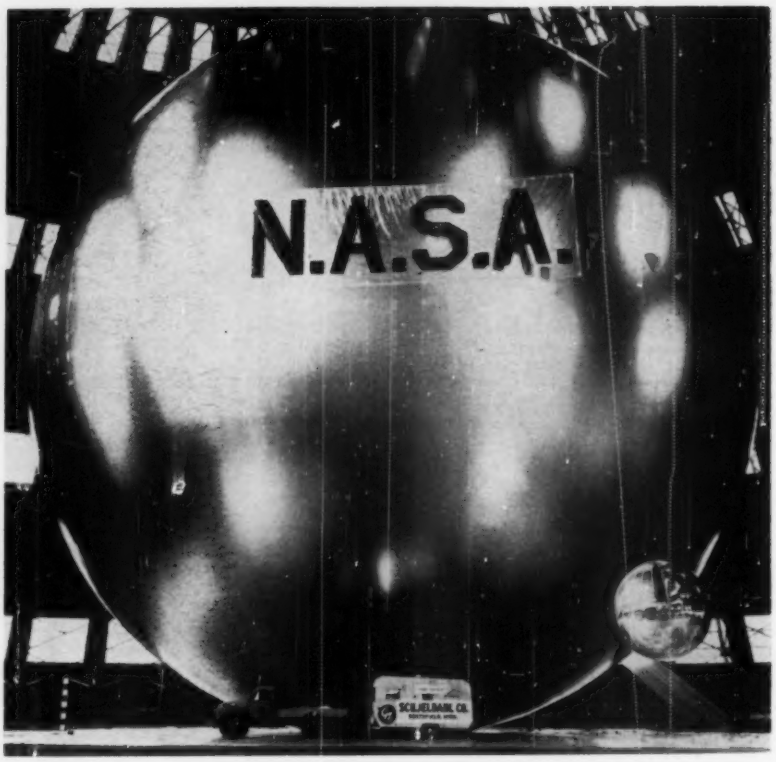
For internal combustion engines, UTAC records pulses with the crankshaft turning at 60 rpm. To ensure equal spacing of pulses around the tape disk circumference, the engine sparkplugs are removed and the crankshaft turned over by an electric motor operating through a gearbox.

Usually, 100 pulses per crankshaft revolution are recorded on tape for a first rough run to spot natural frequency and the magnitude of torsion angles that develop when the motor runs at its normal speed range. Some 200 pulses are generally recorded for high-accuracy runs, which permits measurement of torsion angle at 200 points during each revolution of the crankshaft.

During test runs, the two magnetic heads pick up the pulses previously recorded on tape. Corresponding pulses from the two tapes are compared in electronic circuits that transform phase differences caused by torsion angles into voltage signals. These are fed to an oscilloscope, along with time markers and top-dead-center pips obtained photoelectrically from the tape disks.

—Art Erikson, Paris Bureau

NASA blows a big aluminum foil balloon



This colossus of balloons, Echo II, is shown just after passing its first test before being launched to space. The sphere has been succesfully expanded to its full 135-ft dia under high-pressure injection of helium and air. The skin is Mylar, laminated on both sides with a special ultrathin aluminum foil, and is said to have survived four times the strength required for an orbited space flight. Sometime next year, Echo II will be launched by NASA to evaluate the effectiveness of bouncing radar and radio signals off aluminum for better earth communications. It weighs approximately 500 lb, compared with 130 for Echo I, and has 82% more reflecting surface than its 100-ft-dia ancestor.

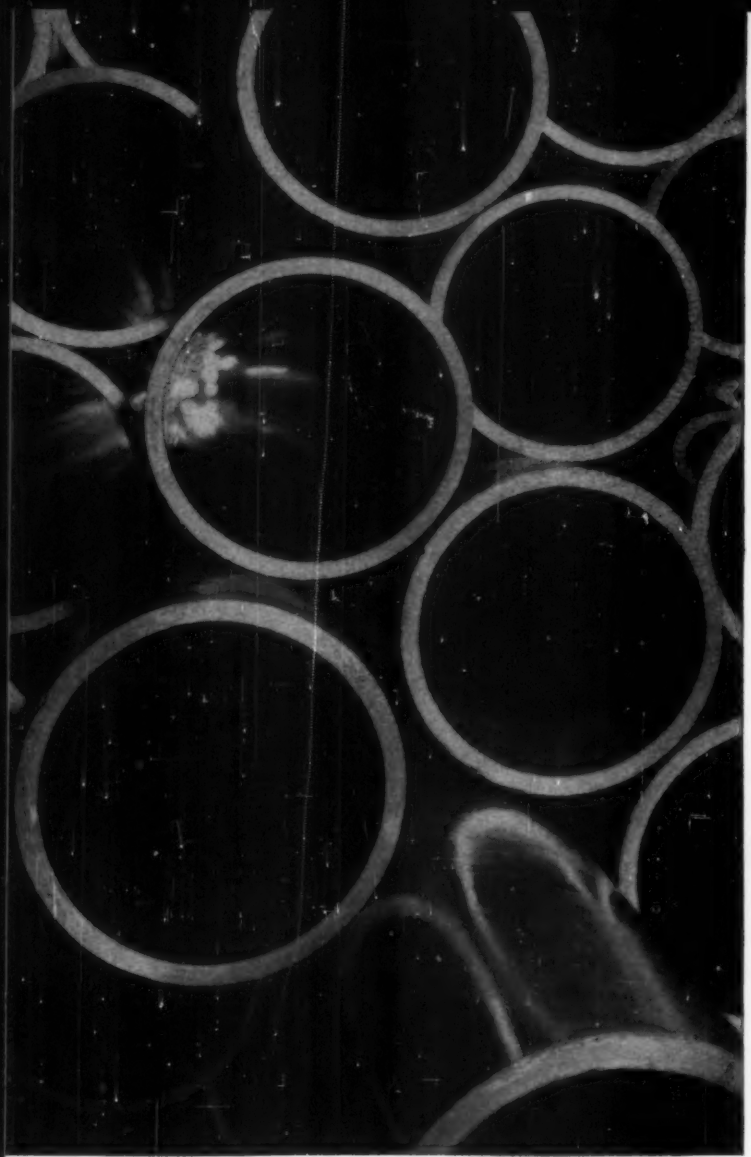
Superconductive alloy promises wide electrical applications

CANOGA PARK, CALIF—A new superconducting material—at cryogenic temperature it offers negligible resistance to electrical current—has been developed here by the Atomics International Div of North American Aviation for the Atomic Energy Commission. The material is a cold-worked alloy, about three parts niobium to one part zirconium.

A wire, which can be coiled easily, has reportedly been drawn from the new material. At the temperature of liquid helium (−452 F) it has conducted 100,000 amp per sq cm in a moderately high magnetic field (300,000 gauss).

The alloy is said to be malleable and strong, and also workable into bars, strips and other shapes without losing its superconducting properties. It is expected to retain these characteristics in substantially higher magnetic fields, enabling fabrication of superconductor magnets that may replace conventional bulky and relatively inefficient iron-core electromagnets. The superconductor versions would have no iron core and may produce magnetic fields many times stronger than today's conventional electromagnets.

It is believed that superconducting electromagnets of 100,000 gauss strength used with high-energy particle accelerators or with controlled thermonuclear research devices could substantially reduce operating costs for such equipment. And the electromagnets may be important in space technology where weight-cutting is important: They could store more electrical energy in less space. ■



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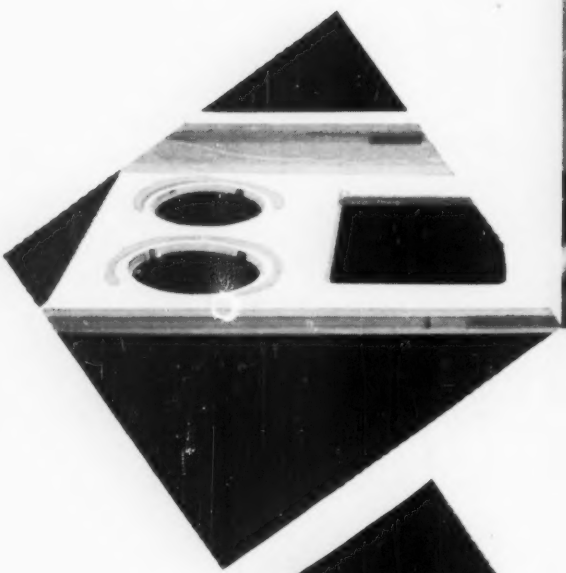
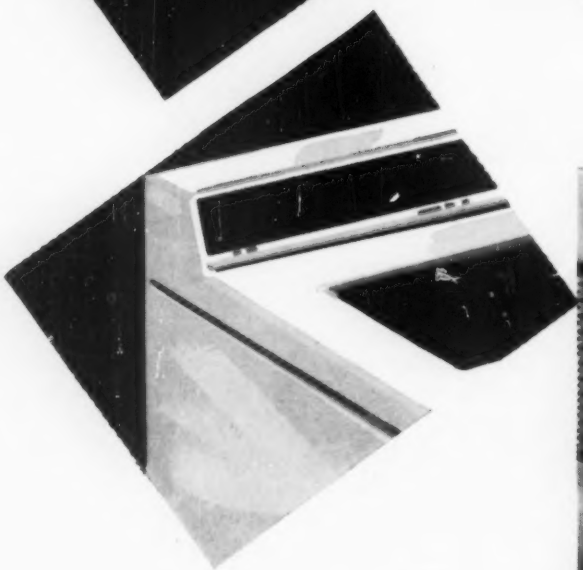
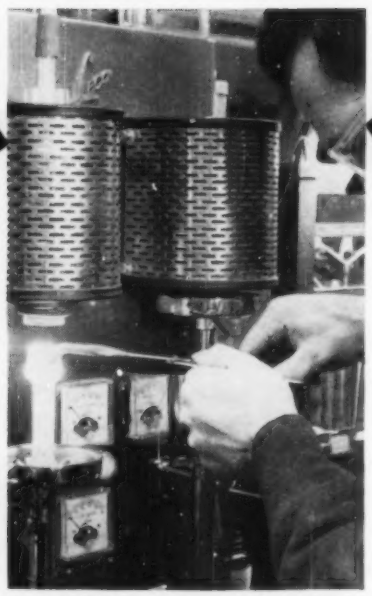
CIRCLE 21 ON READER SERVICE CARD

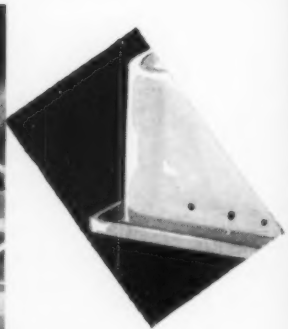
Proper grain size—vital to drawing properties—is checked microscopically before each lot of Armco Enameling Iron or UNIVIT is shipped.



DESIGN FOR With







Armco UNIVIT is closely checked to assure virtual absence of carbon.

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Armco UNIVIT® opens new vistas for product designers, permitting one-coat, one-fire porcelain enameling without danger of boiling or fishscaling. A porcelain enamel finish "direct-on" Armco UNIVIT fights abrasion and corrosion, provides exceptional resistance to mechanical damage and thermal shock. Cost? It compares favorably with baked enamel or vinyl finishes.

Porcelain Enameled Steel

For color, form, durability

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2 Armco Enameling Metals

For high-quality two-coat porcelain enameling, Armco Enameling Iron has long been noted for its excellent enameling properties, workability and freedom from sag in firing.

Together, Armco UNIVIT and Enameling Iron offer wide latitude for designers seeking to give their products the color, form and durability of porcelain enamel. For complete information, write **Armco Division, Armco Steel Corporation, 2021 Curtis Street, Middletown, Ohio.**

ARMCO **Armco Division**

Blow molding dominates nation's plastics show

Blow-molding machine of German origin (most of those displayed were from West Germany) was only one in show to fully exploit continuous nature of the extrusion process. Its mold section rises to enclose parison as it leaves the extrusion die. Mold then closes and descends as actual molding takes place and extrusion continues. At end of molding period, mold opens and rises to meet and enclose newly extruded section.

MONTE LEVIN, *industrial designer, NYC; John Kalb, assoc editor*

■ Blow-molding machines and materials dominated the ninth National Plastics Exposition, held in New York, June 5-9. This process (see PE—Jan 16, p 50, for complete details), which puts the extrusion principle in direct competition with the more traditional types of molding equipment, is still in an early stage of its growth—for example, only one of the machines exhibited (above, right) approaches full exploitation of the continuous nature of the extrusion process.

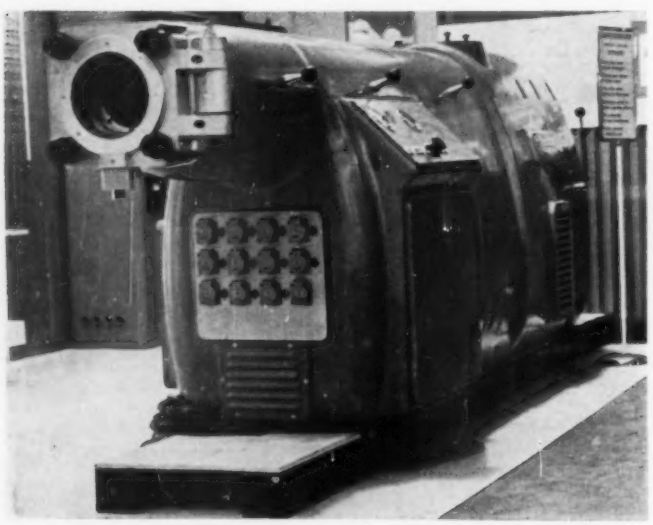
Among new materials applicable to the blow-molding process was a polycarbonate from General Electric. It's first of its kind to offer nearly water-clear clarity with flexibility—and it can withstand 300-F heat, putting it in competition with many standard glassware applications. Along with properties similar to low-density polyethylene, plasticized vinyl and rubber, this thermoplastic copolymer possesses elastic properties though it's formulated without a plasticizer.

Also displayed were examples of the very large parts and structures producible by "Thermofusion." This process fills relatively inexpensive sheet metal mold with special grades of powdered polyethylene and then fuses the powder in an oven. Length of time in oven determines wall thickness.

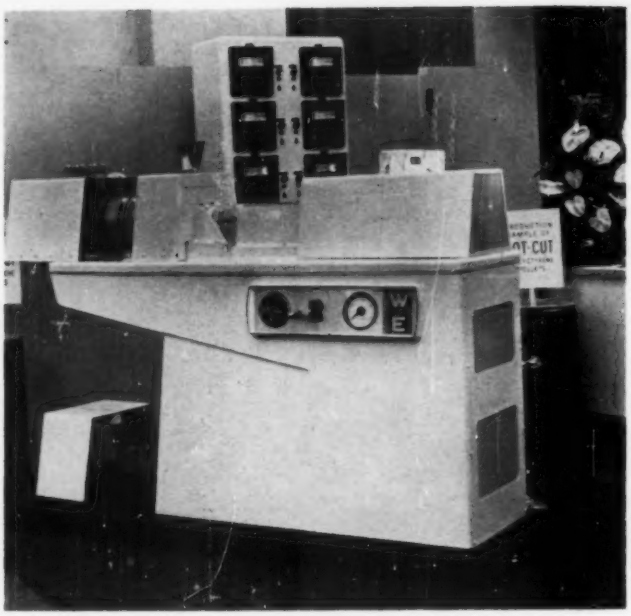
One of the applications for plastics exhibited by a number of companies was the self-hinge. This integral means of attaching covers and mechanical elements to containers and housings is growing fast, and its penetration of those machine design areas where the standard types of mechanical joint prevail has barely begun.

Better material uniformity and strain-free moldings have been achieved by the automatic, 12-oz injection press made by F J Stokes Machine Co; Stokes re-designed the drive components into a single, in-line system.

Although the plastics industry is much younger than metalworking, just about as few of the various machines in each field exhibit clean, efficient lines and well thought-out control arrangements. Some of the better examples are shown on these pages. ■

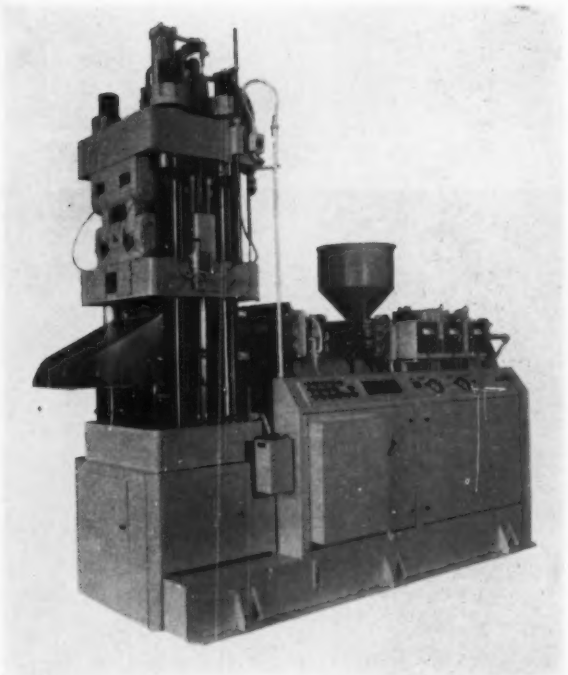


Production extruder from Germany owes its relatively soft and plastic lines to basic arrangement of its principal mechanical systems, such as the drive, gear reducer and extruding screw.



Extruder for experimental and development work made by Welding Engineers Inc has simple lines and minimum bulk that should ease maintenance, but control area-trademark panel has been unnecessarily prettified with color and a silver-finish laminate.

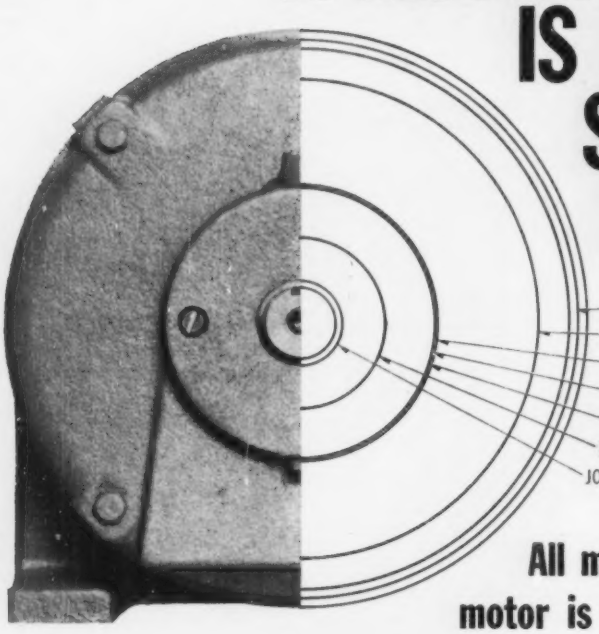
Polyethylene beer case provides perhaps the most dramatic application of the self-hinge. Basic cost of this container is three to four times that of the paper case it replaces, but it eliminates deterioration by moisture, is waterproof (can be packed with ice) and stands up well enough under re-use to be offered on a deposit basis.



Automatic molding machine is based on single straight shaft that links the screw in plasticizing cylinder with the piston in ram cylinder, located directly behind it. This means the machine can inject molding material with less pressure than required in the thrust-bearing system traditional in such equipment. Less pressure means strain-free moldings. Also, using a screw plasticator allows substituting mechanically produced heat for a large portion of the electrical heat input normally required in injection molding, making this machine especially suitable for heat-sensitive plastics. Made by F. J. Stokes Machine Co.

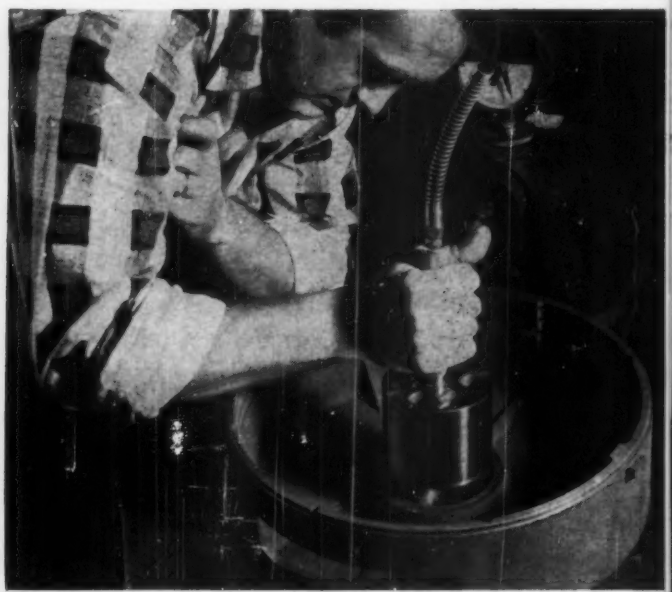
Heat fusion of polyethylene powder to give products as large as baby cribs, 500-gal. tanks and floor trucks (author Levin is shown examining them) is accomplished in process that gets by with relatively low-cost sheetmetal mold and heat—but no pressure. Process is slow, but labor costs should prove lower than for most other processes capable of producing such large moldings.

A MOTOR IS A SERIES OF CIRCLES



All must be ACCURATELY CONCENTRIC if the motor is to run smoothly, quietly, trouble-free

CONCENTRICITY of Elliott C-W Motors begins with the bracket-to-frame fit, the reference for all subsequent "circles." Bearing bore and shaft bore are precisely centered within this accurate diameter.



TOLERANCE of 0.0007 in. for the bearing bore is checked by an air gage after finishing in a precision lathe. Master jig assures accurate positioning of bearing, essential to uniform air gap.

Elliott Crocker-Wheeler integral-hp a-c and d-c motors—from smallest to largest—are offered in all conventional enclosures and modifications; with insulation to suit the application, including EPOSEAL epoxy insulation, for use where conditions are most severe.

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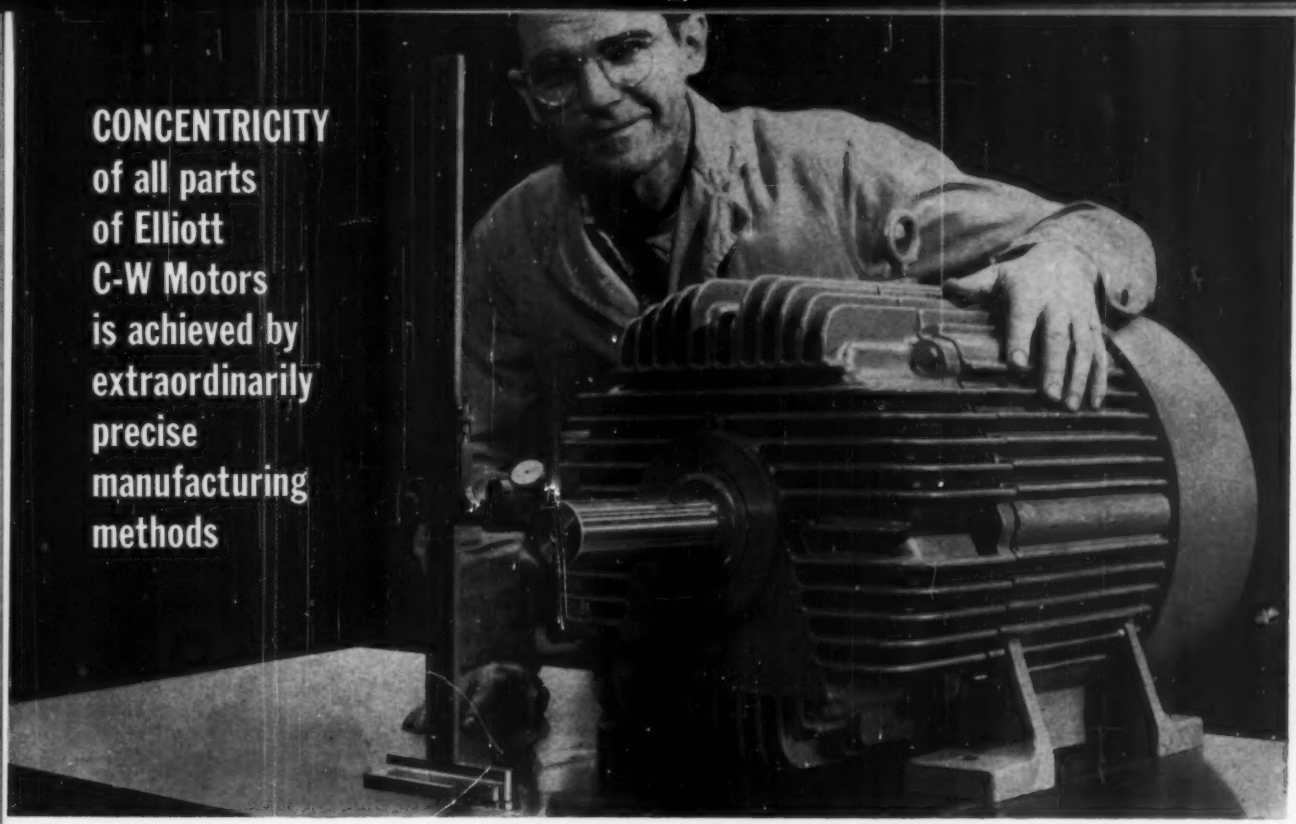
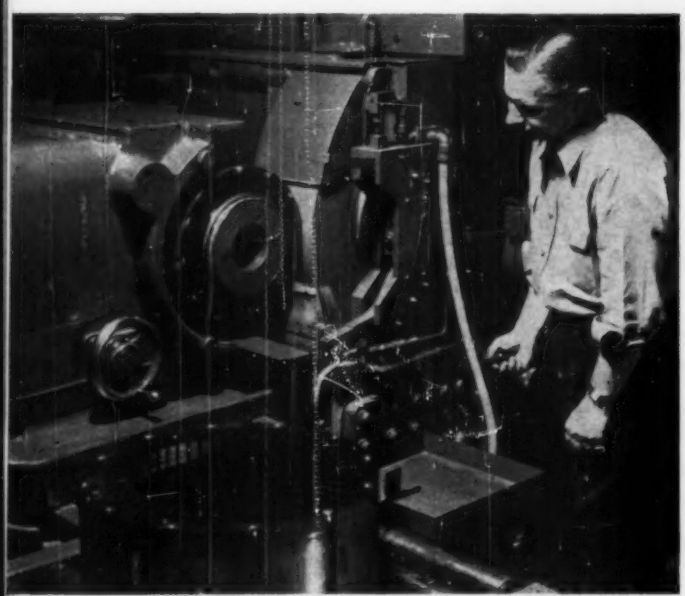
CIRCLE 26 ON READER SERVICE CARD

CONCENTRICITY of all parts of Elliott C-W Motors is achieved by extraordinarily precise manufacturing methods

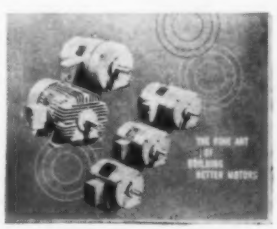




PRECISION GRINDER finishes the outer surface of the stator core to a tolerance of 0.001 inches. It is then pressed and keyed into stator frame, which has been finish machined concentric with the basic bracket-to-frame fit.

DUPLICATING the basic bracket-to-frame fit, a jig accurately positions the wound stator for finishing the inside core diameter by a "fly cutter," which corrects for all accumulated tolerances and assures precise concentricity.

Key manufacturing operations employed in maintaining the required close tolerances are described more completely in an interesting brochure, *The Fine Art of Building Better Motors*. We will be very glad to send you a copy.



W1-2

PE

ELLIOTT COMPANY, Jeannette, Penna.
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28 CIRCLE 28 ON READER SERVICE CARD

READER TO EDITOR

Keep present patent system

To the Editor:

I have read the article by Mr Frankel in your May 8 issue, suggesting "improvements" for our patent system, and feel obliged to correct what appear to be serious misconceptions concerning the nature, purposes and function of the patent system.

What Mr Frankel appears to object to is the practice of inventors selling the rights to their inventions for a price which, he feels, is inequitable. He overlooks the fact that the Constitution and the patent laws are intended only to create a property right and not to insure that the property right is sold for a fair price. Under the existing system the patentee, like any owner of property, is free to bargain, and to sell or not sell his property as he sees fit, for any amount he desires. Mr Frankel, it appears, would single out the patent as the one type of property which could not be sold as its owner sees fit, but must be sold only according to a contract written by the government and determined (by whom?) to be equitable to both buyer and seller. This in itself would drastically limit the patent right by prescribing what the patent owner could or could not do with his right.

Let us now examine the existing system about which Mr Frankel finds objection and determine if the system really is inequitable. The inventor-employe now sells, by agreeing to assign to his employer, any patents he may obtain and in payment receives a generous salary every pay day. Forgetting the employer's investment in the facilities and equipment which the employe uses, the employer is still making a substantial investment by way of salary in the employe himself, and is gambling that the employe will make an invention that will repay this investment. I wonder how many employe-inventors would be willing to gamble their own salary on their ability to produce a worthwhile invention. Chances are, if an employer offered the prospective employe a very large percentage of the profits from any of the employe's inventions if the employe would work with the employer's facilities and equipment without compensation, there would be very few, if any, who would wish to take this gamble. Mr Frankel's system would have the employe share in the winnings but not in the risk; and this is contrary to what I believe every one has come to realize as a basic fact of life, ie, we can only expect to gain in production to what we risk—anything else is a gift.

Any careful consideration of the proposed system will reveal innumerable sources of trouble and practical problems which would most probably make the operation and administration of the system prohibitively expensive, if not practicably impossible. To suggest only one such problem: Who is going to administer this system and how are they going to do it? I submit anyone attempting to give a full, complete and carefully considered answer to just this one question will soon

come to realize the nature of the "monster" which Mr Frankel would create.

Our patent system, like most everything else in the Constitution, is extremely well conceived and has functioned well since its inception. For these reasons most of us who work with this system every day are very reluctant to suggest or agree to changes in the system, and then only after such changes have been subjected to the most thorough study and have survived the most severe scrutiny. Mr Frankel has failed to submit any evidence that the system is in need of revision.

—Robert E. Corb,
Attorney at Law
Lexington, Mass

Longer fatigue life—why?

To the Editor:

In "New Developments in Bearings and Gear Lubrication," May 15, p 58, you reported our tests indicate that "the lower viscosity oils gave longer fatigue lives than the higher viscosity oils—though there are not sufficient data to prove this conclusively." Your statement is correct; however, you should also have included our opinion that this might have been the result of different base stocks.

—E A Baniak and G A Kohl
Texaco Research & Technical Dept
Beacon, NY

COMING EVENTS

JUNE

25-30 . . . . American Society for Testing Materials, 64th Annual Meeting Chalafonte-Haddon Hall, Atlantic City, NJ

26-30 . . . . American Institute of Electrical Engineers Conference on Concepts and Design in Aerospace Electricity, Benjamin Franklin Hotel, Philadelphia

26-28 . . . . American Society of Heatin, Refrigerating and Air Conditioning Engineers, Annual Meeting, Denver-Hilton Hotel, Denver

28-30 . . . . Institute of Radio Engineers, ASME, AIEE, ISA, AIChE, 2nd Joint Automatic Control Conference, University of Colorado, Boulder

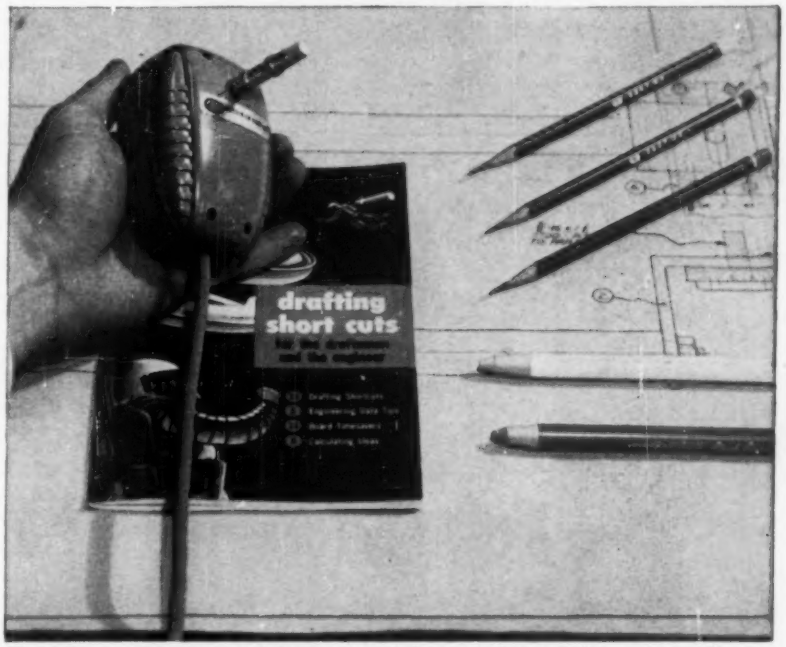
JULY

9-14 . . . . Instrument Society of America, IFME, AIEE, IRE, 4th International Conference on Bio-Medical Electronics & 14th Conference on Electronic Techniques in Medicine & Biology, Waldorf-Astoria Hotel, NYC

18-20 . . . . Western Plant Maintenance and Engineering Conference and Show, Pan Pacific Auditorium, Los Angeles

For a listing of addresses of societies and associations send 25¢ to Product Engineering Reader Service Dept, 330 W 42nd St, NY 36. Ask for brochure R 32.

DRAFTING TRENDS



Three Post aids to increased drafting speed shown clockwise: Self-switching Mercury electric eraser; Triangular-shaped Try-Rex drawing pencils; Peel-off eraser sticks.

New drafting conveniences increase efficiency

Mercury Electric Eraser—Try the full-automatic Mercury eraser for really effortless corrections—it turns *on* when you pick it up, turns *off* when you put it down. So quiet and vibration-free that it takes a touch of the high speed shaft to convince you its interference-free motor is running!

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Try-Rex Drawing Pencils — Embodying the first new pencil design in years, a rounded, triangular casing, the Damascus Try-Rex pencil provides more than a relaxed and comfortable grip. Its three flat sides not only fit the controlling three fingers, but indicate to the draftsman a succession of 120° stops which help position the pencil for uniform line weight and density. Precise grading of lead hardness, plus color-tip coding, further aid production of better tracings and clearer prints.

Pencil-Style Eraser — An eraser capable of hairline control often saves re-drawing of fine detail in small-scale work. For such precise work, there's nothing better than a Post 2934 Pink Pearl eraser, now available in peel-off, self-sharpening pencil style. The Post 2933 Magic-Rub is also a paper-wrapped, peel-off type, but provides a white vinyl tip for clean erasing of drafting film. Both give real convenience when exacting erasure is needed.

Further information on all of these worthwhile Post drafting aids is available from your nearest Post dealer. Or, write Frederick Post Company, 1642 North Avondale Avenue, Chicago 18, Illinois.

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The fastest d-c motor response... with new fan cooled Life-Line H motors

On-the-line test results (at the right) conclusively show the faster response of 30 hp d-c Life-Line H fan-cooled motors with these design improvements:

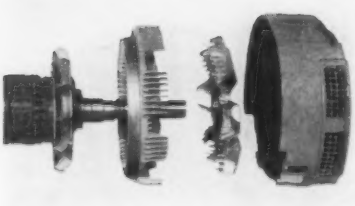
- 75% reduction in armature inertia
- 500% commutating ability for accelerating
- 30% reduction in electrical time constant

Similar motor performance throughout the line provides faster starts, quicker stops, faster reversing, precise regulation of speed and torque. This enables you to increase production, improve product quality and eliminate costly processing complications.

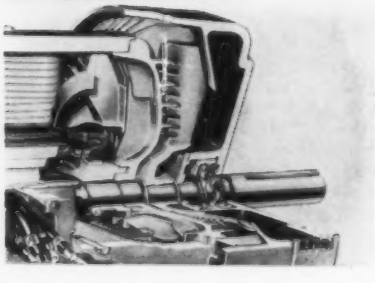
The unique cooling system combines a built-in heat exchanger with air-over-the-motor ventilation which permits smaller frame sizes per horsepower delivered. Result: less mounting space; less weight.

In addition, this rugged TEFC Life-Line H motor offers many other advantages:

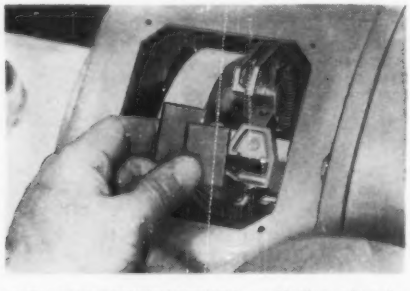
- Screened air intakes, cast end brackets, and tight seals throughout provide resistance to liquids, vapors, dirt and dust.
- Self cleaning fan eliminates the possibility of clogging or fouling.
- Location of bearing and the outboard bracket increases bearing life when load is belt-driven.
- Uniforce* brushholder assembly automatically maintains constant brush pressure throughout the normal life of the brush. *Trademark



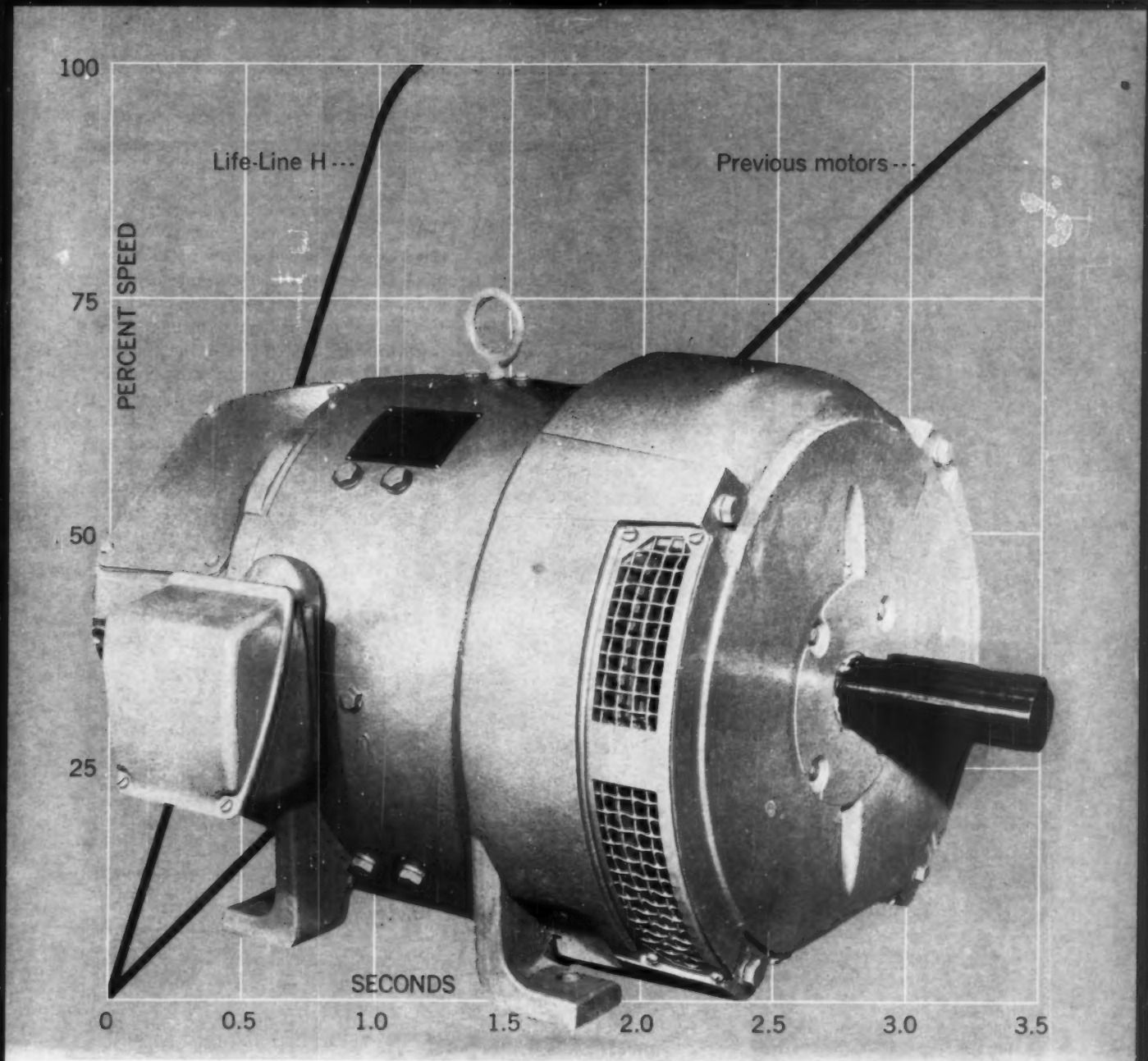
UNRESTRICTED AIR FLOW . . . The internal fan creates an air flow which directs internal heat to the aluminum heat exchanger. The external fan draws air through the bracket bottom and side openings, cooling the total surface of the heat exchanger. The air continues unrestricted over the frame for additional cooling. The meshing action of the fan and heat exchanger fins provide self cleaning action as demonstrated above.



OUTBOARD BEARING LOCATION, LONGER LIFE . . . Exclusive outboard bearing construction keeps foreign matter out. Bearing-to-load position remains the same as in drip-proof motors for longer bearing life and less possibility of shaft breakage under any load condition.



LOCK OUT BRUSHHOLDERS . . . Uniforce brushholder fingers lock-out . . . brushes can be inspected or changed with one hand. Tension remains constant throughout brush life, no need to adjust pressure as brushes wear. This field proven design also provides smooth brush ride and continuous contact for sparkless commutation.



Your Westinghouse motor specialist is equipped with full information on how this fast acting d-c motor will fit into your production scheme. Call him for help on specific applications, or write Westinghouse Electric Corporation, 3 Gateway Center, P.O. Box 868, Pittsburgh 30, Pa.

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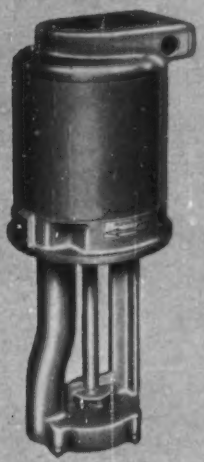

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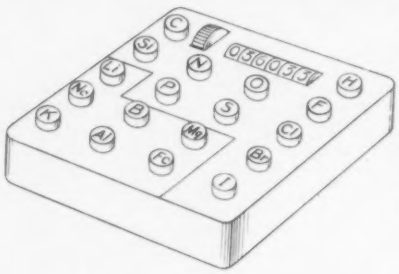
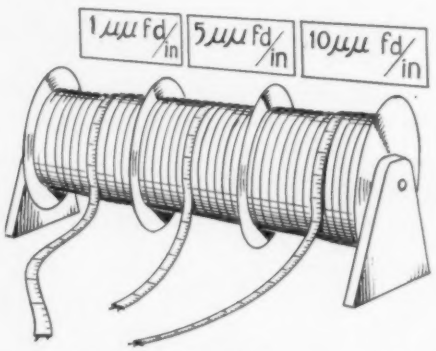
WHY DON'T THEY R&D..?

. . . a special-purpose desk calculator for the chemical industry. When a chemist wants to find a molecular weight, he must first look up the atomic weight of each element in the molecule, multiply by the number of atoms and add the results of each multiplication. Why not provide an attachment for a desk calculator with a key for each of the common elements? Depress the "carbon" key and it would automatically set 12.011 into the calculator. This could then be multiplied and added, using the "accumulative multiply" of the calculator. Such a device could be simply a set of mechanical levers made to slip over the keyboard of the desk calculator.



Or perhaps an inexpensive pocket calculator could be made, similar to the sketch at left. Depressing the "carbon" key three times would give the atomic weight of three carbon atoms Keys could be arranged in an order roughly corresponding to their position on the periodic table. —D S Erley

. . . poured wooden floors. They could be laid over subflooring, concrete or old floors much faster than nailing down individual boards. Just set up border dams, pour on the flooring and allow to harden. If a board-like pattern is desired, egg-crate dividers could be laid on the floor before pouring. These could extend slightly above the poured surface and be cut back flush during final sanding. Recent experience with epoxies, chip-board and sawdust board might prove useful in developing a good-looking flooring with the "give" and resilience of wood flooring. —R Marie



. . . adjustable "fixed" capacitors for electronics laboratories. These could be simply a pair of foil plates or wires imbedded in a dielectric, looking something like TV lead-in wire. The cable would have marks at uniform increments, each representing a specified number of picofarads. Different-color cables would be provided for different values of capacity per unit length. For a capacitor of a given size, you would simply strip one end of the cable and snip off the needed capacity. The circuit could then be tuned by trimming pieces off the end of the capacitor. —C Perko

Have you a problem, based on known scientific principles, which seems to have an answer somewhere within the limits of present technology? To inspire inventors along worthwhile paths, PRODUCT ENGINEERING invites you to trade such problems with readers who have a fresh viewpoint or more time to experiment. We pay $10 on acceptance.

B.F.Goodrich

New way to protect your metal product... a temporary but tough coat of Geon

Panels for this building were coated and fabricated by Elwin G. Smith Company, Pittsburgh, using "Strip-Gard" strippable vinyl coating made with Geon vinyl by Stoner-Mudge Company, Pittsburgh, a Division of American-Marietta Company. It can be applied by all standard methods including brush, reverse roll, spray, dip, flow and conventional roll coating. B.F.Goodrich Chemical Company supplies the Geon vinyl.

Here's a temporary coating that goes on metal fast, strips off easily. Meanwhile, it gives polished, embossed or coated metals protection during fabrication, storage and shipping. It's an organosol based on Geon vinyl.

Since the coating stretches well and is very flexible, you can corrugate, emboss, roll-form or draw metals coated with it without affecting the coating. In some cases, it eliminates the need for lubrication. Wear on expensive plated or polished dies is significantly reduced. And there's no need for final cleanup after fabrication or assembly.

Because it's made of Geon, the coating protects metals from the effects of oil, grease and from discoloration or etching of corrosive chemicals. It provides excellent resistance to scratching or abrasion. The manufacturer says it's not designed to protect against weathering, but it will—tests show no staining or embrittlement outdoors for periods up to six months. And the desirable stripping qualities are not impaired.

Here's another way that Geon vinyl is opening new markets, making possible new or improved products. Want more information? Write Department NO-4, B.F.Goodrich Chemical Company, 3135 Euclid Avenue, Cleveland 15, Ohio. In Canada: Kitchener, Ontario.

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Geon VINYLS

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You get **MORE THAN A MOTOR** with General Electric's Form G...for example...

Years Ahead Design Leadership

Form G leadership among fhp motors isn't accidental. We work hard at it, constantly improving, constantly innovating. We've found it's the best way to help our customers keep ahead of the changing demand in their industries. It's good business on our part. It's good business on your part too . . . to make sure you get the advantages a years-ahead motor can offer your product.

In addition to design leadership, you get these MORE THAN A MOTOR benefits with General Electric Form G motors: *Ease of Assembly . . . Expert Application Aid . . . On-time Delivery . . . Versatility Personified . . . Fast, Local Service.*

THESE YEARS-AHEAD FORM G MOTOR FEATURES MEAN LONG LIFE, RELIABLE PERFORMANCE

1. RELIABLE SWITCH — Centrifugally-operated switch has been life-tested to last for more than 3,500,000 operations. Dependable switch mechanism operates with positive snap action.

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6. COMPLETE LINE—Over 850 basic models—and literally thousands of variations—mean there's a standard Form G motor to meet your product's *exact* requirements.

* Reg. Trademark of Du Pont Co.

You receive these *added values* at no extra cost. So why settle for less?

Form G fhp motors are available in NEMA 48 and 56 frames. For more information, call your G-E Sales Engineer or write for bulletin GEA-6424 to Section 721-06, General Electric Co., Schenectady 5, N. Y.

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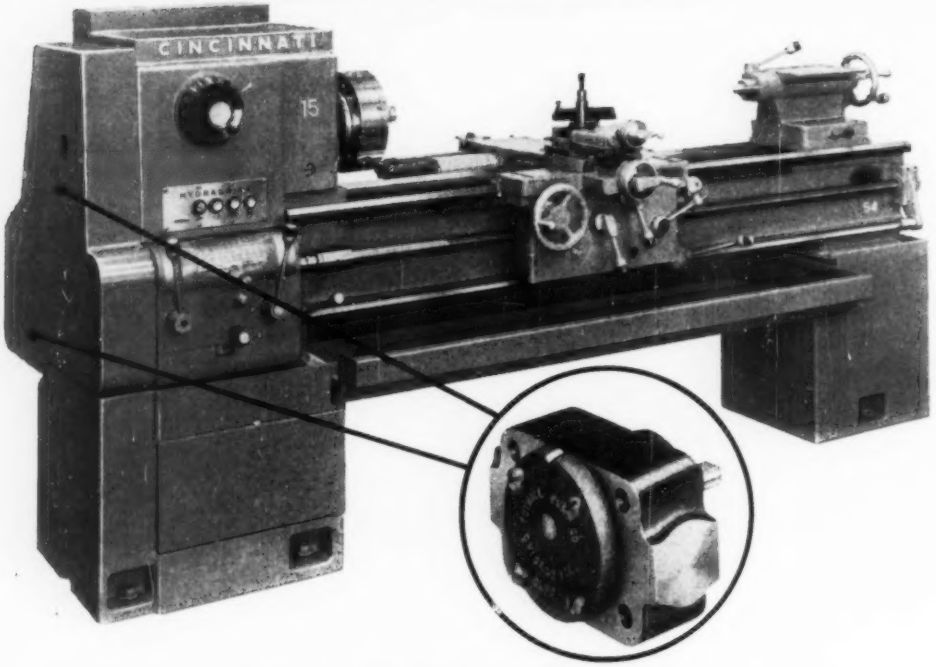
Another pump problem . . . solved by TUTHILL



TUTHILL PUMPS For Hydraulics, Lubrication in New Cincinnati Hydrashift Lathes

Cincinnati's new Hydrashift lathes use hydraulic power instead of muscle for spindle speed shifting. Entirely new from headstock to tailstock, these dependable units reflect in every way the quality and reliability long associated with this leading machine tool manufacturer.

Cincinnati selected Tuthill pumps for two vital assignments . . . to provide hydraulic power for Hydrashift preselective speed shifting . . . and for positive pressure lubrication of the entire unit. Minor modifications of a standard Tuthill cartridge pump, Series RFD, enable it to meet the requirements of both applications . . . providing interchangeability and allowing incorporation of both units with the greatest possible ease on Cincinnati's assembly line.

Wide Selection Available From Stock

Tuthill's versatile and dependable cartridge pumps have been used for hundreds of applications . . . both as OEM components and for maintenance. Their compactness solves design problems . . . for example the Model RFD above measures only $4\frac{1}{4}$" by $2\frac{1}{2}$" by $3\frac{15}{16}$" including shaft. Moderate prices and immediate availability from stock minimize inventory problems, result in significant savings.

Cartridge pumps can be supplied for capacities from 55 to 360 gph at 1800 rpm. They are available with or without Tuthill's special reversing feature which allows them to be driven from reversing shaft or for nondirectional service. They may be supplied with internal or external porting . . . or with variations of both. Three different standard shaft modifications are offered and many more are available.

Send today for Catalog 100 which gives complete details . . . or send information on your particular application so Tuthill's engineers can indicate ways in which a Tuthill pump can save you money.

Tuthill manufactures a complete line of positive displacement rotary pumps in capacities from 1 to 200 gpm; for pressures to 1500 psi; speeds to 3600 rpm.

PUMPS FOR YOUR PURPOSE

TUTHILL PUMP COMPANY

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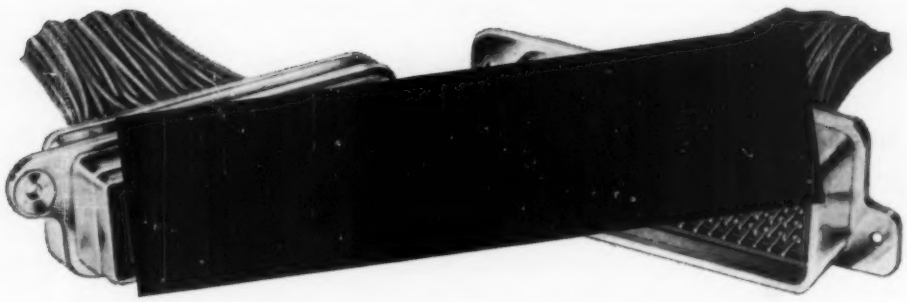


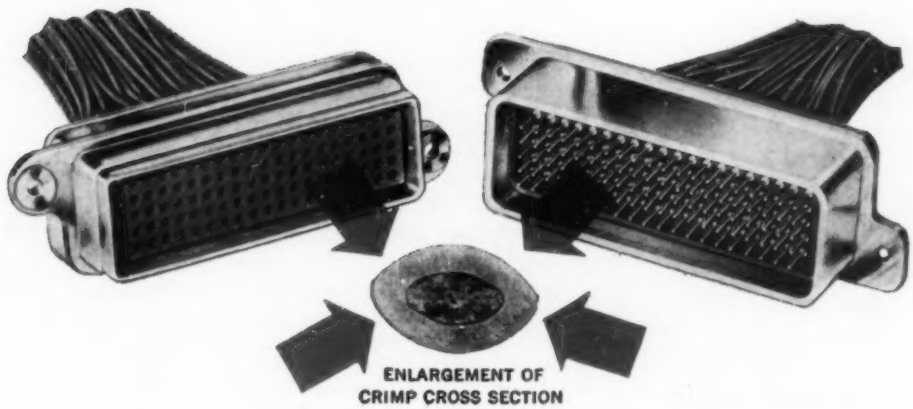
IT'S NO SECRET...

IT'S THE CRIMP THAT COUNTS! Line 'em up! Look 'em over! They're as much alike as midnight sheep jumping for a sleep-searching count and . . . with good reason! Most of them have a great deal in common — materials, design and construction.

It's this look-alike, act-alike quality about connectors that makes AMPin-cert connectors stand out. Only AMPin-cert gives you the one very important difference in connectors — AMP's industry-accepted solderless termination technique . . . a controlled-pressure, compression-crimp whose reliability is backed by twenty years of research, development and production.

Does the difference stop here? Definitely not! AMPin-cert not only gives you extreme reliability but also . . . high-level production of terminations, up to 1,500 per hour on the AMP-O-LECTRIC automatic machine . . . quick "snap-in" assembly of contacts in the block with finger-touch ease and an extraction tool that makes routine checks, maintenance and circuit rearrangement "snap-out" easy.

Want to base your connector choice on something more than blind-fold logic? Then . . . get the whole story on AMPin-cert connectors. Write today for the catalog — "AMPin-cert CONNECTORS (Pin and Socket Type)".



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Value Analysis Fact Sheet

ANACONDA FREE-CUTTING BRASS ROD

Not the plain old work horse many think, it can be produced with a variety of valuable properties—in addition to high machinability—to do many special jobs better, and at lower cost.

For the great majority of high-speed screw machine jobs, free-cutting brass rod is a standard shelf item.

But in an increasing number of jobs, the free-cutting property alone is not enough. Deep drilling to close tolerances, roll-threading, knurling, staking, slotting, etc., call for uniformity in a variety of other property combinations.

Fortunately free-cutting brass is a unique "on the fence" alloy (see Metallurgical Comment at the right) that can be adapted to answer these new demands—help screw machine operators meet increasingly rigid requirements and utilize cost-saving practices.

Specialized applications. Over the past several years, Anaconda American Brass has introduced several refinements into the usual mill practice for free-cutting brass and has developed different rods for specialized applications. In most instances, these rods will still meet ASTM and Government specifications.

Chip breaking. For the user who demands a rod with uniform ability to break up into small chips, an alloy is supplied which regularly contains substantial quantities of beta. This, because it is brittle at room temperature, adds to the chip-breaking ability of the lead already there. This rod is, therefore, particularly good for high-speed forming and drilling applications. On the other hand, it is the least ductile and can therefore be formed and headed to the least extent.

Cold forming. The usual and more numerous special applications require uniform ability to be cold-worked—as in roll-threading, knurling, heading, and other deforming. Properties of these special rods are refined by heat treatment or special drawing operations so that the rod can be consistently cold-worked. Normally, there is little sacrifice in machinability, but there is some loss in the ability of the rod to break into small chips.

Deep drilling. In small rod particularly, there has been an increasing demand for material that can be drilled to close tolerances. Special drawing and heat treating practices were developed to produce a rod which performs uniformly, even in such exacting applications as ball point pen tips.

High Strength. And for those applications calling for uniformly higher strength than the usual material, there is a rod produced by special drawing practices.

Technical assistance. If you have a special problem—whether it involves a variation of free-cutting brass or another free-cutting or engineering copper alloy—call in your Anaconda American Brass representative. He'll make available to you the experience and services of metallurgical and mill specialists. Or write: Anaconda American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 6148A

FOR MORE INFORMATION about Anaconda Rods for Screw Machine Products—including physical properties, mechanical properties, composition and machinability — write for Publication B-14. Address: Anaconda American Brass Company, Waterbury 20, Connecticut.

Metallurgical Comment

Free-Cutting Brass can provide relatively wide variations in temper and ductility within the range of composition defined in ASTM and Government specifications (60 to 63% Cu, 2.5 to 3.7% Pb, remainder Zn).

In the commonly available rod temper, referred to in ASTM specifications as "half hard" and more commonly in the trade as "hard," tensile strength may range from 50,000 to 70,000 psi, depending on the rod size and the manufacturer.* And there can be a comparable variation in cold-working properties.

Here's why. The range of 60 to 63% copper was selected for free-cutting brass because it is the lowest which can be used to produce an alloy that can be hot-worked readily and also cold-worked. This means a brass that can be hot-extruded down to small sizes—and that later can be cold-worked to a modest degree.

In more technical terms, free-cutting brass is at the transition point between the alpha phase (the ductile form of the alloy) and the beta phase (the form that's hard and brittle at room temperature but readily worked when hot). Thus, relatively minor changes in composition and fabrication practices can make substantial shifts in the proportion of alpha and beta grains—hence in strength and ductility. Various combinations of these properties can be maintained uniformly by careful control of mill practices.

Free-cutting property of the alloy is, of course, provided by lead dispersed through it—and is not materially affected by changes in other properties.

Standard Anaconda Free-Cutting Brass-271 has a composition of 61.50% Cu, 3.25% Pb, 35.25% Zn. This composition and the mill procedures used are designed to provide a rod which will fit the great majority of high-speed screw machine work.

*In special hard temper the tensile strength of small sizes will approach 90,000 psi.

ANACONDA®
FREE-CUTTING ROD
Anaconda American Brass Company

PRODUCT ENGINEERING HORIZONS

June 26, 1961

Leader, not dictator

So Trujillo—at long last—is gone. His was the end that comes to most dictators, sudden and violent. But ambitious men never learn that ordinary men can suddenly rise above themselves if the cause is great enough.

This is, presumably, the best time in which to live—at least in the United States—more people have more and better things than ever before. But in the midst of all this plenty—the billions of dollars that are used in power politics, the storehouses full of over-production, the burgeoning birth rate—in the world at large, the emergence of a middle class has been slowed and the growth of the lower and underprivileged class increased.

Four out of five of the three billion people now living in this world have never had, and will never have in the foreseeable future, what we Americans consider a good square meal. Four out of five have never seen a doctor—and never will. Even in such a basic thing as literacy we are losing ground. In 1951, about 48% of the world's children were going to school. By 1958, this had been pushed up to 55%. But last year it had fallen to 53%, and was still on the way down. Of the 550 million children five to 14 years old, only 300 million are in schools. Only 8 million of 25 million African children make it—and of these, fewer than 5% get to secondary education. Only 1% of the teachers there are African, so chaos lies ahead.

Sobering statistics like these point to our current problems—misapplication of funds, misuse of resources, misunderstanding of the relationship between people and food. Similar mistakes toppled earlier civilizations.

What do these have to do with you—beyond your connection with them as an American citizen?

We have given of our engineering and production knowledge to the world, you say, with as large a hand as we have given of our funds. What more can the world want from a leader?

But we have given of these as a rich man gives alms—and have generated the same resentment. We have not cooperated—in the eyes of other nations—so much as we have thrown pennies to the poor.

Further—and this is the engineer's fault directly—we have given the wrong things! Why don't we provide the peoples of the world with the things *they* think they need rather than what we think they should have? A compact car is no good to a mountaineer, a vacuum cleaner is an insult to the farmer's wife without electricity.

And this isn't just, "wouldn't it be nice if . . ." We *must* be leaders, not dictators, or we won't be leaders long.

new-lube-free

Sterling's variable speed drive never requires lubrication

STERLING
Sealed and shielded bearings require no lubrication.
Keys are fabricated from tough elastic material to eliminate key and keyway wear.
Wear-resistant non-metallic bushings require no lubrication.
Shaft surfaces are corrosion-proof and require no lubrication.

All lubrication maintenance problems are eliminated by Sterling's new variable speed drive. Fret corrosion is completely eliminated. Sticky pulleys, resulting from improper lubrication, are no longer a problem. Belt life is lengthened; pulley wear is eliminated.

Special load-bearing surfaces never require any attention or lubrication. Keys and bushings will not wear out. Shaft surfaces are also tough and wear resistant.

Sterling's new "Lube-Free" variable speed drive can be installed in any location, no matter how inaccessible, since lubrication maintenance is no longer needed.

Complete application and product information is available by writing Dept. S-4, Sterling Electric Motors, Inc., 5401 Telegraph Road, Los Angeles 22, California—or by contacting the Sterling field engineer in your area.

Tough shaft surfaces provide unusual chemical resistance and anti-frictional properties. Specially fabricated keys and bushings hold up indefinitely.

Hathaway INSTRUMENTS INC.

Sterling Electric Motors, Inc.

5401 TELEGRAPH ROAD, LOS ANGELES 22, CALIFORNIA,
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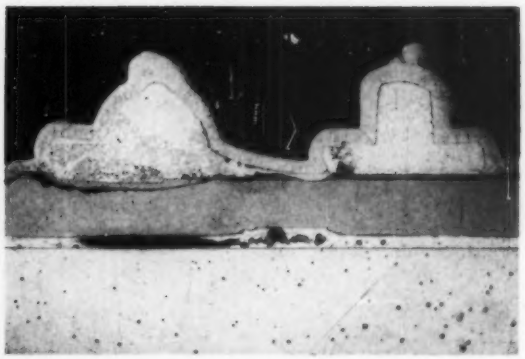


HIDDEN SHORT CIRCUIT burned out one lead to transistor (left). Photomicrograph above (250X) traced trouble to solder bridge between contact points, which bypassed the semiconductor.

TROUBLESHOOTER'S approach to FAILURE ANALYSIS

Increased reliability—that's why you want to pinpoint any weak link in design. Authors tell where and how to look for the unexpected in the newer miniaturized designs.

H S DODGE, *supervisor, failure analysis*
R G LULL, *research engineer*
Burroughs Corp

■ The failure of a part, whether in laboratory test or field operation, is useful when it feeds back data showing inadequacies in design. This is a practical way to raise reliability of a complex assembly because it pinpoints the weak link. Then, strengthening the weak link can raise reliability of the entire design. But first, you need a failure-analysis group to locate the failure, determine its cause and recommend steps to prevent the failure from recurring.

Most investigations of part failures require:

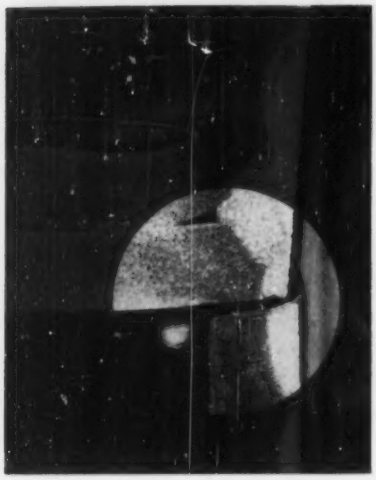
1. To determine if the material meets requirements and whether the part is within specifications.

2. To determine if service loads differ or exceed those expected in the original design.

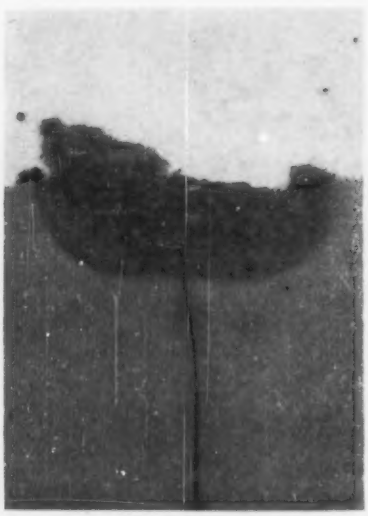
For both, adequate records of the part and its service are the easiest source of information. Though such records cost money, this cost may be small in comparison to a recurring failure that cannot be traced. When each part carries its own serial number, records can show the material's chemical composition, strength and hardness. These records can also give the source for a purchased component, indicate when the part was made or assembled, its inspection record and the complete service history.

But this amount of paperwork for each part is impra-

REPRINTED—Circle 613, inside back cover



POOR WELD PENETRATION (left) led to break in this aluminum sheet-metal joint. Weakness was corrected (right) by fillet weld which eliminates the sharp stress-raising corner. (magnification: 7X)



INTENTIONAL DAMAGE diagnoses cause of failure. Problem here was failure of a welded joint between a current-carrying wire and a semiconductor material. Failure (left) could be either mechanical or electrical. Cross-section of assembly broken by mechanical load (center), compared with joint subjected to electrical overload (right), established that the failure was mechanical. (magnification: about 2000X)

tical, especially for small parts made in large numbers—here, cost of the records would be excessive. Therefore, practical failure analysis usually has to start with fewer clues.

The original part

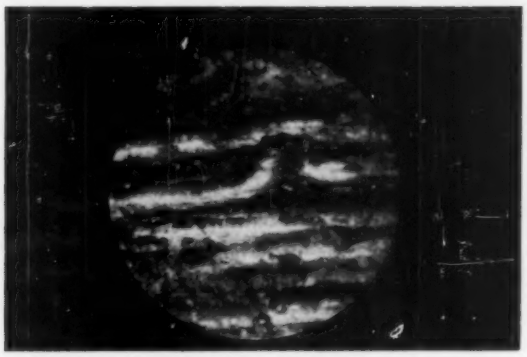
Even when only small broken fragments are recovered for analysis, much of the data on the original part can be obtained. Records are a help. For example, a lot number will permit the following tests to be made on unused parts from the same lot.

Hardness—one of the easier tests. It can be checked, even on small surfaces, by mounting the sample and testing its hardness by microscopic methods. More than giving a mere check against the specified value, hardness of the metal will show if it is the wrong material, whether it has been given the correct heat treatment—and sometimes will indicate such service conditions as overheating.

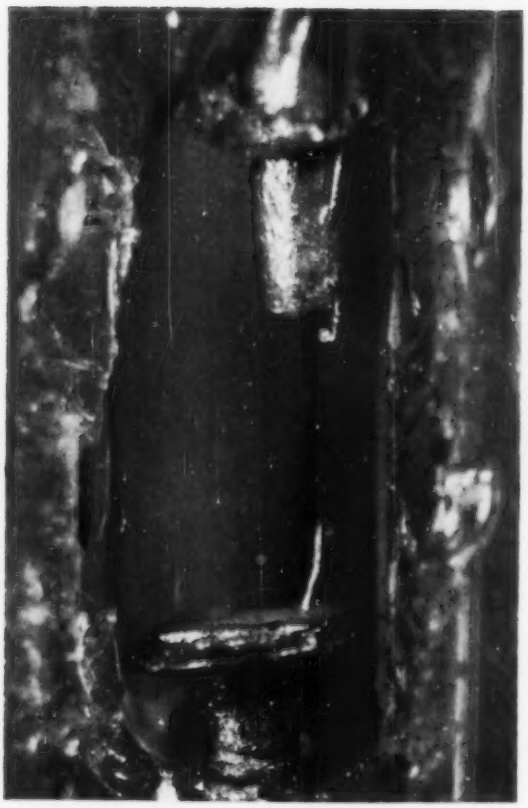
Dimensional accuracy. Even if inspection records show that the original part passed dimensional checks, remeasurement of the part and its mating components might show such faults as dimensional changes in service, inadequate clearances, interfering fits.

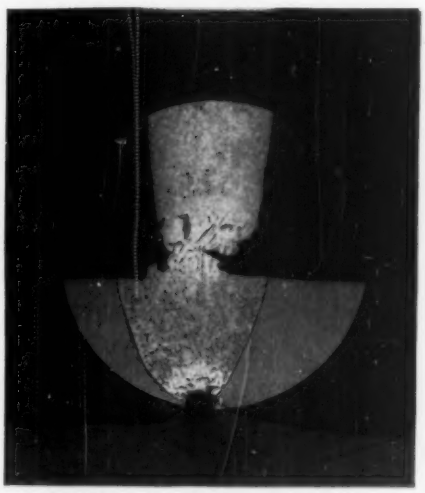
Chemical analysis of the material. Complete chemical tests can be run if the part is large enough—usually about 6 grams of metal is required for wet chemical tests. Often such rough tests as chemical spot tests are sufficient to confirm the material. Where the composition is critical, small amounts of metal can be analyzed by microanalysis techniques, by spectrographic or X-ray methods.

Mechanical properties of material in the part are more difficult to test, but are a must when failures are mechanical



INADEQUATE INSULATION caused this miniature transformer to burn out. Contributing to failure were manufacturing defects—uneven winding and kink in wire visible in photo above. (magnification: left, 3X; above, 30X)





CURRENT OVERLOAD caused failures which differ with direction of the current flow in these germanium diodes. Excessive forward flow (upward direction, photo at left) melts the gold whisker wire, with little damage to junction. Excess current in reverse direction (above) heats the junction and alloys the wire with wafer material, causing short circuit through the semiconductor wafer. (magnification: left, 30X; above, 750X)

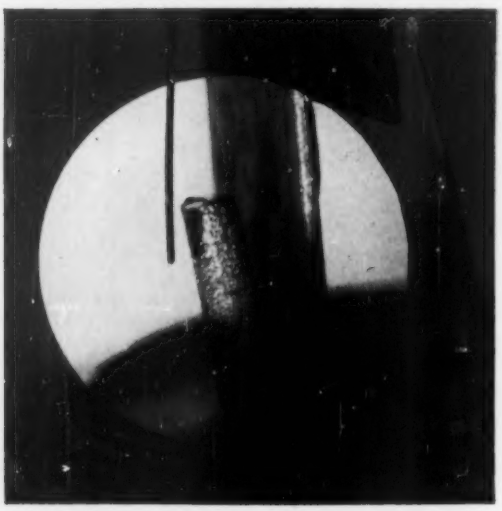
or structural. Usually there is too little material to test, the easier way then is to trace back to property data in the original material. If there is sufficient material for tensile tests, results should be compared with strength of the basic material before it has been fabricated or formed, with allowance for property changes from manufacturing processes. For example, the more complete specifications for castings have two sets of property requirements—one for test bars, the other for specimens cut from the part itself.

Microscopic examination of mounted specimens will reveal such faults as wrong grain size or metallurgical structure, internal flaws such as microshrinkage, and such manufacturing defects as decarburization and incomplete welds or brazes. For miniaturized electrical and mechanical components, high magnifications are a must because the defects are not visible by eye or even at low magnifications. When manufacturing on these miniature parts must be done under microscopes, one important requirement is inspection at a magnification at least 3 to 4 times higher. In addition, the specification must spell out what makes it a good or sound part.

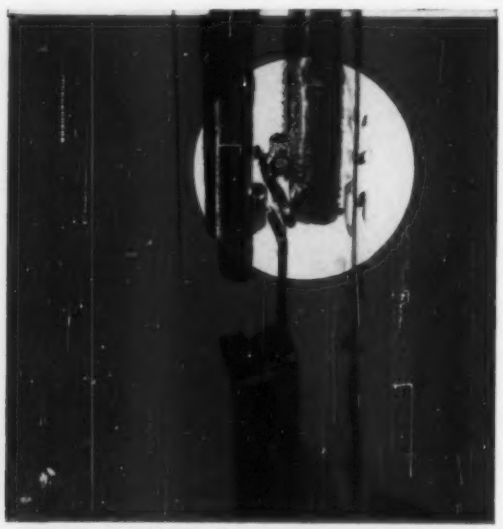
continued, next page

1. REPORT NO. | 2. INITIAL REPORT NO. | 3. REPORTING ACTIVITY | 4. MISSILE TYPE | 5. SYSTEM SERIAL NO.
6. FAILED ITEM PART NO. | 7. FAILED ITEM S/N | 8. FAILED ITEM NAME | 9. FAILED ITEM MFR. | 10. FAILED ITEM REV. DESIG.
11. NEXT ASSY. PART NO. | 12. NEXT ASSY. NAME | 13. NEXT ASSY. MFR. | 14. NEXT ASSY. REV. DESIG. | 15. SYSTEM NO.
16. FAILURE CODE | 17. F/I REPT. CODE | 18. SUBSTITUTE PART NO. | 19. REPLACEMENT S/N | 20. DATE OF FAILURE DAY MONTH YEAR
21. TIME: HOURS MINUTES SECONDS | 22. CYCLES | 23. MONTHS | 24. MILES
25. FAILURE DISCOVERED DURING: .1 BENCH TEST .2 INSPECTION .3 STORAGE .4 SHIPPING .5 CHECKOUT .6 MAINTENANCE .7 MFR. TESTING .8 OPERATION
26. REASON FOR REPORT: .1 FAILED ITEM .2 T. O. DIRECTED .3 TIME EXPIRED .4 OTHER
27. REPAIR OR DISPOSITION ACTION: .1 REPAIRED IN PLACE .2 REP. & REINSTALLED .3 ADJUSTED .4 ELIMINATED .5 CONDEMNED .6 HELD FOR REPAIR .7 DEPOT REPAIR .8 FAILURE ANALYSIS
28. REPLACEMENT: .1 IDENTICAL PART .2 SUBSTITUTE PART .3 NONE NEEDED .4 NOT AVAILABLE
29. DESCRIPTION OF TROUBLE
REMARKS
29.1 WAS ITEM MARGINAL? .1 YES .2 NO
30. REPORTED BY
SMQD NO. 0-80, 10 MAY 57 FAILURE AND CONSUMPTION DATA
31. DATE RECEIVED | 32. DATE REPAIRED
33. FINAL DISPOSITION SIGNATURES
.1 CONTRACTOR ENGINEERING
.2 CONTRACTOR QUALITY CONTROL
.3 GOVERNMENT QUALITY CONTROL

STANDARD FORM (both sides shown) for reporting field failures. As developed by Burroughs, it is designed to cover all possible causes, and requires minimum judgment.



POORLY WELDED WIRE separated and opened this circuit. Fault was elminated by spelling out inspection requirement—inspection must look for slight flattening of the wire, which shows good resistance weld. (magnification: 25X)



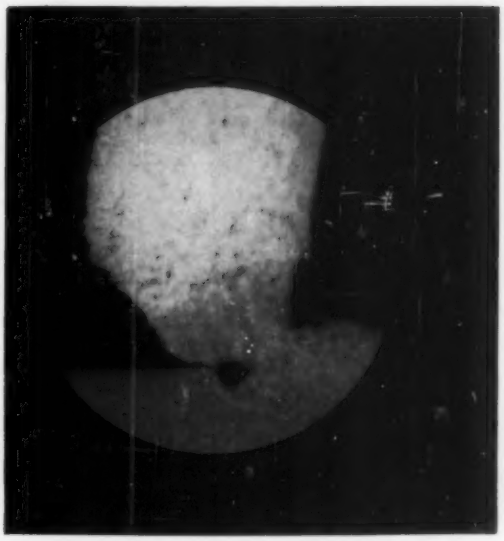
ARCING CAUSED FAILURE—external circuit, rather than the mercury-wetted relay itself, was at fault here. Adequate arc suppression would have prevented relay contacts from welding. (magnification: 5X)

The service record

First step here is to compile a complete operating history of the part that failed, particularly the circumstances just prior to failure. This part of the record should be compiled by people trained to report objectively. Field failure at remote sites are particularly difficult to diagnose. Standardized forms for reporting the failure help obtain complete information on the failure. A typical form, shown at top of this page, when completed will usually give sufficient data.

When the analysis reveals that material and part were normal when initially installed, the system should be

FAILURE STATISTICS PROVIDE THE CLUE. Sound when electrically tested, diodes like this one had high incidence of failures at the junction.



Checking undamaged units at a magnification of 1000X (above) showed mechanically weak connection—a flaw detectable by production inspection.

checked to determine if loads were too severe. The type of failure or overload usually give clues to the cause. For example, when the broken pieces assembled together show bending, the deformation will give direction of stress and show that the loads exceeded the yield stress. Brittle breaks at a flaw, notch or other stress concentration usually indicated fatigue or recurring stresses less than the yield strength. These usually start at or near the outer surface where the stress is highest.

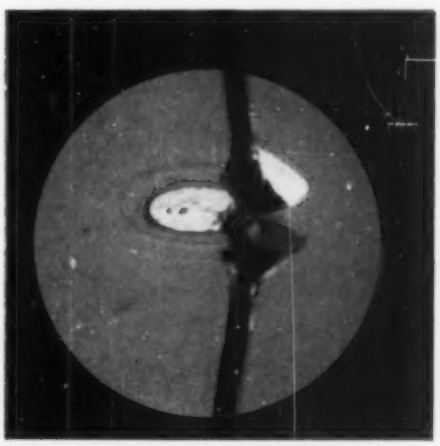
Failures in electrical components may have more remote causes. For example, a wire melted by excess current may be traced to a faulty circuit breaker or an external short circuit; a relay with contacts welded together by arcing shows that the circuit design lacks sufficient arc suppression.

Statistical records on failed parts will give clues and sometimes the direct cause. They may suggest how to prevent further field failures even if the cause cannot be found. For example, if the failures are limited to one lot from one maker, the cure might be simply to recall all assemblies with that lot number and continue the testing in the laboratory.

One common technique is to compare the broken part with an undamaged one—particularly useful where standard tests on the material itself cannot be performed. This is common for small or miniature parts. By comparing the units side by side small differences become apparent. These are not as readily visible when visualizing the damaged part alone.

Intentional damage is another technique used to determine the mode of failure when several causes are possible. This method consists of breaking or damaging the part by known causes, and then matching these breaks against that of the failure under investigation.

For REPRINT of above article, just check 613 on one of the Reader Service cards found in this issue.



SOLDER DOT SLIDES SIDEWAYS when external overheating softens or remelts the connection and wire has a side pull. (magnification: 100X)

EDITOR'S NOTE: For additional information on failure-analysis techniques and other methods to improve product reliability:

How to Avoid Metal Hose Failure, July 25 '60, p 43—In high-pressure, high-temperature service, the hose can last a hundred years—or fail in minutes. This article lists causes of failures and how to overcome them.

Why Bearings Fail, Oct '56, p 167—A systematic description of the most common causes of failures, and remedies.

A Manual of Reliability, May 16 '60, p 65—This comprehensive special report explains the role of failure analysis in improving reliability. It tells what reliability is, how to calculate and measure it, and how to design a reliable product. A reprint of this 32-page report is available for 50 cents from our Reader Service Dept, Product Engineering, 330 W 42nd St, New York 36.

—Herbert Kee

Take some plastic nitrile rubber, blow it in a mold with nitrogen, vulcanize it to shape, and you have a low-density structure strong enough to take industrial hydraulic pressures.

they float . . .
CELLULAR RUBBER GIVES RIGID LIGHTWEIGHT PARTS

GENE KASK, *chief engineer*
Willimantic Div
Rogers Corp

When you need a complex, rigid plastic shape of unusual lightness, such as a carburetor float or a buoyant plug for a fluid-metering device, cellular nitrile rubber may be the answer. The shapes shown above are made from Nitrophyl, a nitrile rubber blown with nitrogen and vulcanized to the "ebonite" stage. This forms a closed-cell structure that can be designed to withstand hydraulic pressures as high as 2000 psi.

The properties

As with any blown material, the nitrile rubber has properties depending on density of the cell structure and shape and size of the molded part. By varying the material and the processing, a range of densities from 10 to 38 lb/cu ft (held within ±1 lb /cu ft) have been produced; densities over 38 lb/cu ft are possible. For the most commonly specified material (10 to 12 lb/cu ft density), the following mechanical properties are typical: compressive strength of 300 psi, flexural strength of 750 psi, and impact strength of 0.1 ft-lb/in. Higher density structures have proportionately higher properties; for very high-pressure applications, special stocks and processing techniques are employed. Any given grade will withstand higher pressures if the part is made smaller and more compact.

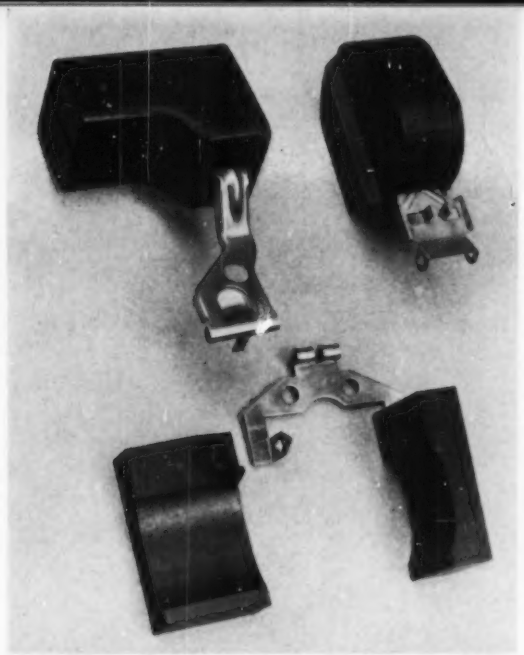
Thermally, the blown and vulcanized nitrile rubber parts will withstand continuous service at temperatures from −70 F to 250 F. The material is thermoplastic and softens slightly at 240 F, so that concentrated loads or high pressures should be avoided above about 230 F. Floats of this material have tested satisfactorily in oil at 350 F.

Chemically, cellular nitrile is very resistant to most fluids, including fuels, lubricants, solvents, transformer- and hydraulic-oils. Some increase in weight is normal, but is usually less than 5%. If the skin is pierced at installation or during operation, fluid absorption increases slightly, though not enough to influence performance of the material. Nitrile rubber is satisfactory in water at room temperature, but does not perform well in hot water. For this environment, a natural or synthetic rubber would be preferable. Fluids in which cellular nitrile parts have functioned satisfactorily are listed in the accompanying table.

Design considerations

Because properties of the material are determined to a great extent by the actual design, it is important to check the following points carefully before specifying the material:

Size limits are determined by ability of the process to provide uniform and controlled cell size. This can be done if the thickness is not less than ¼ in. and not over 2 in. Larger parts can be produced by blowing and curing several layers. These layers, each with its own surface skin, are then bonded together using some of the uncured compound as an adhesive. Curing the laminate gives a structure that is 100% vulcanized nitrile, but with layers of cellular material interleaved with thick reinforcing layers of fused



INSERTS IN CELLULAR NITRILE RUBBER PARTS can be designed many ways to ensure strong attachmen, positive location in the mold during blowing and curing, and stiffness against bending. Parts at top show two different methods for stiffening the insert and gripping it in the molding. Bottom part is a two-pontoon float with one pontoon broken away to show prong design. Inserts can also have knurled or barbed surfaces, or lanced-out tabs to provide grip. Insert is located in the mold during cure by external features that attach to the mold. Shown here as possible locating points: hinge holes, stamped holes, or lanced-out tabs.

skin. This structure is much stiffer than a monolithic piece of the same size would be, so is able to resist higher pressures. The largest laminated piece made so far is a cylinder 10 in. dia and 14 in. high.

Draft is not necessary on surfaces perpendicular to the mold parting line nor are radii on corners required. This is because the molding pressure is low and the mold usually consists of a stackup of several plates, each containing part of the cavity. The mold can therefore be disassembled to remove the part. Conventional molds can also be used without draft if shape of the part is simple. For complex shapes in such molds, use $\frac{1}{2}°$ to 1° draft.

Openings, cutouts, grooves, and holes can be molded, keeping in mind that the part has to be stripped from the mold in a rigid state. Frequently a slight undercut can be added to the surface to act as a "pickup." This will retain the molded part in that part of the mold from which it is most easily stripped. Keep such pickups to $\frac{3}{32}$ in. max so the part can be sprung loose. Use of the pickup can reduce tool cost considerably by avoiding a separate stripper plate. Deep undercuts, shoulders, and cutouts can be handled in stackup molds.

Inserts can be made of any material that will withstand the blowing pressure and the vulcanizing cycle. The pressure is on the order of 25 psig, but varies according to volume and shape. The cycle has two principal variables, temperature and time; a typical cycle would be 320 F for 2 hr. Long molding time tends to keep this cellular

RESISTANCE OF NITROPHYL TO TYPICAL FLUIDS

Common gasolines	Benzene
Kerosene	Toluene
Skydrol	Water (not hot)
Pydraul F9	Alcohol : water (1 : 2)
Pyranol	Alcohol : iso-octane (1 : 2)
Esso Turbo 15	Benzene : alcohol : iso-octane (1 : 1 : 1)

nitrile a "performance" material rather than a "price" material. Stainless steel is the most common insert material because the curing cycle does not discolor it.

An insert must be designed with two features: the part embedded should be roughed or deformed so that the blown rubber will grip it, and provision must be made for its positive location in the mold (see photos). For best strength of attachment, the insert should be embedded to a depth of from $\frac{7}{16}$ in. to $\frac{3}{4}$ in. If the insert surface must remain smooth, or if the insert is of fragile construction, a coating of adhesive will secure it in place. This is expensive, however, because of the extra steps required to prepare the insert for bonding to the cellular rubber. Flat surfaces of all inserts should be located at least $\frac{1}{8}$ in. away from the surface, otherwise slight sink marks may appear in that area owing to the cooling effect of the insert.

Attachments can be made to blown parts without embedment during molding. This is usually done by molding a small hole in the part, filling the hole with a low-viscosity epoxy adhesive, and inserting the attachment. This procedure is not as satisfactory as embedding, however.

Tolerance on dimensions of the molded part itself, or on the location of an insert within the part, is usually ± 0.005 to ± 0.010 in. If necessary, tolerances can be cut to ± 0.003 in.

EDITOR'S NOTE: Other recent articles covering lightweight cellular structures include:

Design Guide for Stainless Honeycomb Sandwich Panels, Dec 5 '60, p 67—An introductory article that gives basics, with emphasis on materials and the practical details of design.

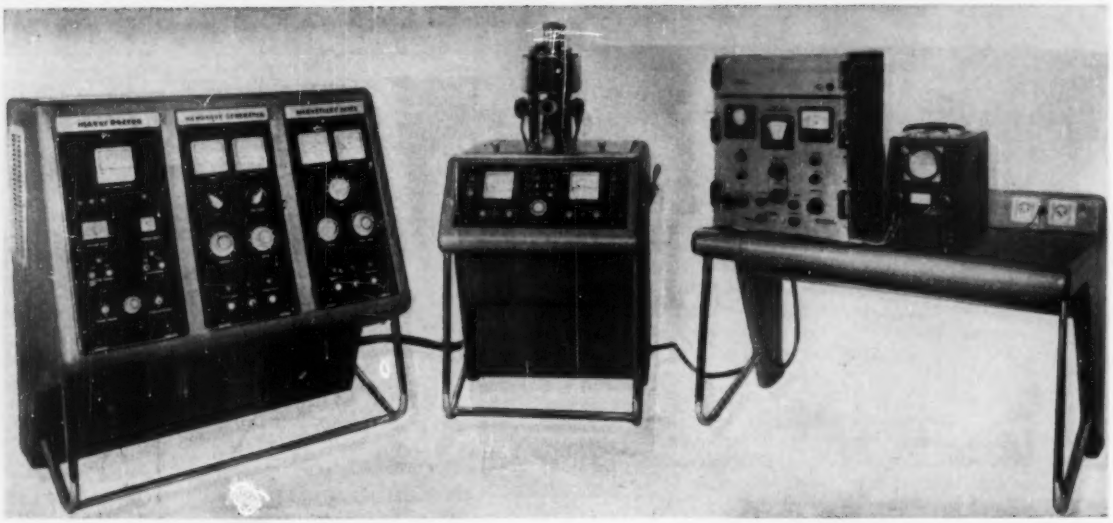
Flexure Limits for Foamed Plastic Sandwich Panels, Apr 13 '59, p 69—Whether you are testing panels or designing them, how they behave under flexure is important. Authors show what causes failure, and how to design on the safe side.

New Foamed Silicones Give Hi-temp Insulation, Jan 5 '59, p 60—Article gives design data on the latest rigid, semirigid and flexible self-curing silicones. Basic library of plastics articles also included.

Best Recipe for Casting Urethane Foam, Nov 10 '58, p 86—Urethane elastomers also have a "rigid" twin brother suitable for many structural applications requiring light weight. Article reviews technology and design procedures.

The Latest on Silicone Rubber Sponge, Aug 4 '58, p 54—Now, with better sponging grades, sharper process controls, and special reinforcing techniques—tolerances can be predicted and rejects decreased.

—Ford Park

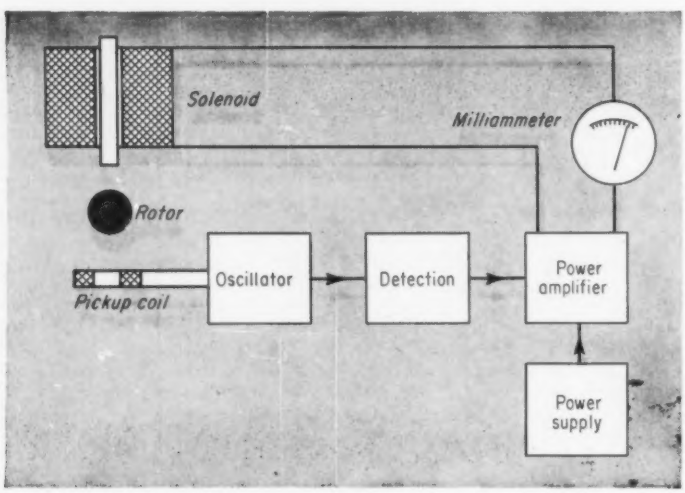


CENTRIFUGE has test rotor of ferromagnetic material. Adhesion of coated film or galvanic coating to rotor is measured by checking the rpm at which applied film is thrown from rotor. This is indicated by a sharp change in the figures on the oscilloscope screen. Adhesion of the test coat is computed from the circumferential velocities and the magnitude of the acceleration expressed as a multiple of the gravitational field of the earth.

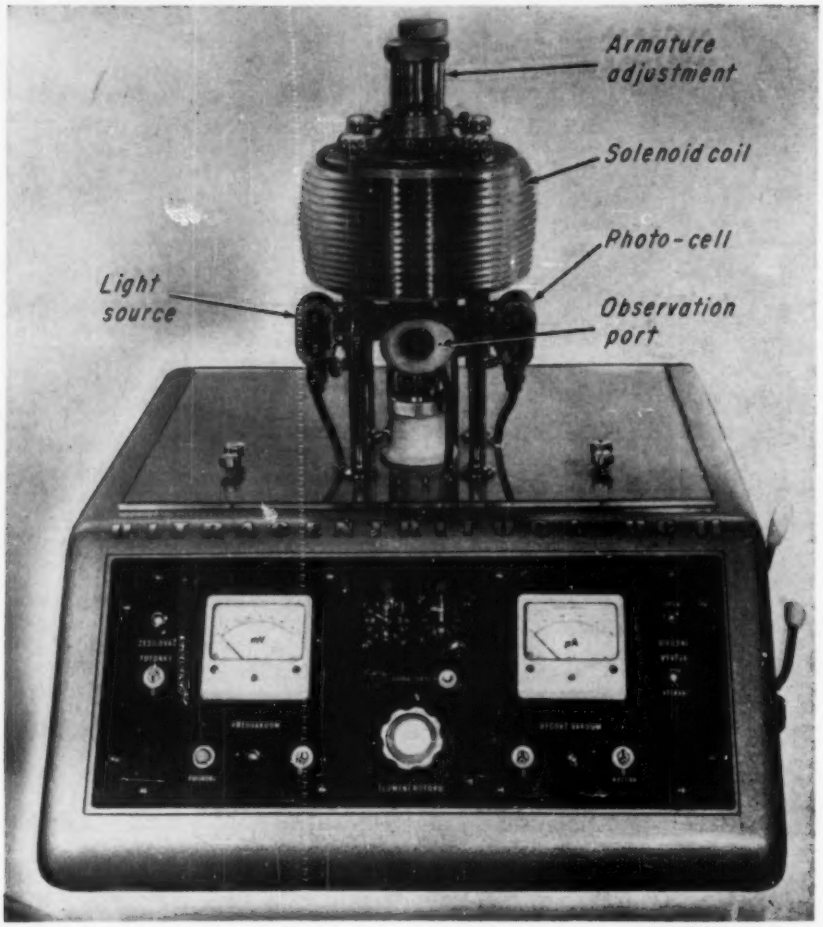
Cohesion measurements, by contrast, spin an uncoated ball until it disintegrates. In addition, extremely low gas pressure may be measured by checking the deceleration of the rotor after the rotor-driving generator has been shut off. Time required for the rotor to coast to a standstill is noted and the deceleration computed. Since the deceleration is a function of the level of the vacuum, slight changes in gas pressure are reflected by the changes in deceleration times.

Frictionless rotor hits 6,000,000 rpm

This centrifuge determines cohesion of ferromagnetic materials and adhesion of their coatings. High velocities are reached by magnetically suspended rotor spinning in vacuum.



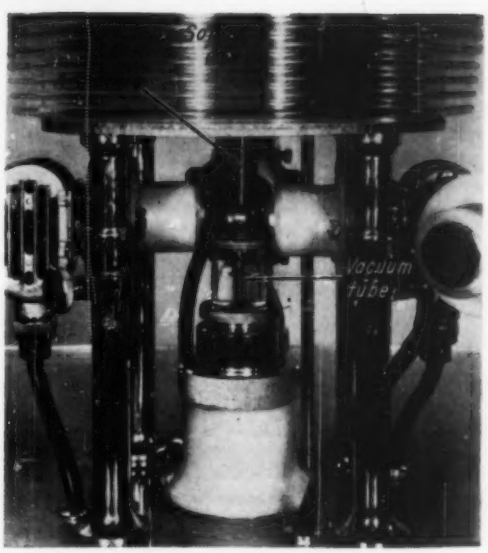
MAGNETICALLY SUSPENDED ROTOR is held in position by a solenoid controlled by a pickup coil under the rotor. This coil is in the grid circuit of an oscillator tuned to bring it and the solenoid cell into resonance when the rotor is in position. Oscillator yields an output voltage sufficient for direct control of the power stage that controls the carrier solenoid. When the rotor sinks, the inductivity of the resonant pickup coil and grid circuit in the oscillator changes. This produces a decrease in output voltage of the oscillator, giving an increase in plate current in the amplifier. The increase in plate current is applied to the carrier solenoid and returns the rotor to its original position.



SOLENOID COIL of centrifuge rotor is suspended above its console on four posts. A ferromagnetic armature adjustable to the required vertical position passes through the solenoid and a glass vacuum tube in which the rotor is placed. The vacuum tube is connected to an oil-infusion pump that can produce a vacuum of 10^{-6} mm Hg. For rapid draw-down, a 2-stage rotory oil pump produces a vacuum of 10^{-3}mm Hg.

Attached to the supporting posts are the rotor-driving coils, fed from the high-frequency power unit. The rotor is observed and positioned through the observation port that passes through the hollow driving coil. A light source and photocell are mounted to check rotor speed.

Rotor rpm is measured by light rays reflected from the rotor to the photocell. The light intensity reflected is varied as the beam passes from the polished surface of the rotor to the surface of test films applied to the rotor. Frequency of variations in light intensity is equal to speed of the rotor. Current produced in the photocell is fed to an amplifier and applied to one set of deflection plates of an oscilloscope. A second set of deflection plates is supplied with a comparing signal from a frequency generator. The figures generated on the oscilloscope are watched until they come to a standstill. At this moment the frequency of reflected light from the revolving rotor and the rotor rpm coincide with the signal from the frequency generator.

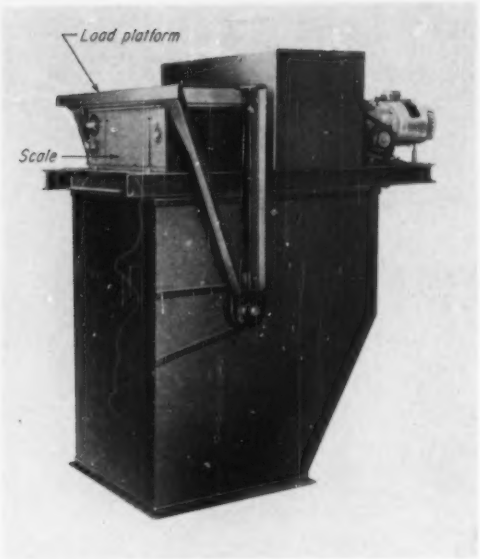


PS . . . Ultracentrifuge uses alloy-steel or beryllium rotors to measure adhesion or cohesion of ferromagnetic materials, measure extremely low gas pressures, determine molecular weight, isolate virus proteins and isotopes. Unit operates with rotors up to 20 mm dia and weighing up to 200 gm. Centrifuge model UC-II-A was designed by Dr Frantisek Einhor for Mikotechna, Prague, Czechoslovakia.

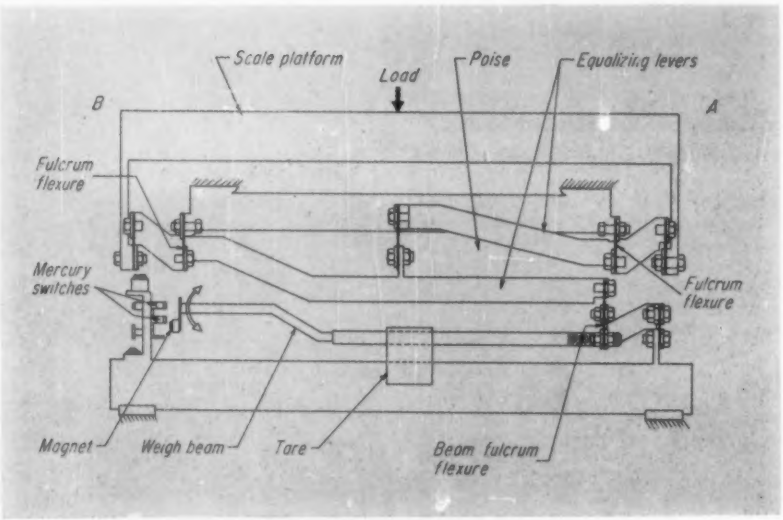
F H Baer, Vienna Bureau

Pivotless scale is friction-free

The flexure plates in this weighing mechanism prevent rubbing friction and wear in dust-filled atmosphere. Resistance to bending is minimized because all the flexures are plumb when scale is in balance.



BATCHING SCALE has pivoted load platform for the material being weighed. When selected weight is reached, scale actuates shutoff to halt flow of material, and the load platform pivots to discharge. Gear motor operates load platform during discharge and return.



PLATFORM LOAD is divided into two components A and B, which are transmitted through the tension flexure plates to the equalizing levers. These levers are suspended by and pivoted on fulcrum flexures anchored to the scale frame. The right-hand equalizing lever terminates at center of the scale and connects to the left-hand lever by another tension flexure. This combines the load components into a single force and eliminates need to center the load being measured. The resultant force is applied to a tension flexure plate which connects the left-hand equalizing lever to the weigh beam. The weigh beam pivots on its fulcrum flexure and its left-hand end rises. When weight on the platform equals the setting of poise and tare weights, magnet on the weigh beam actuates the mercury switches.

Scale-platform movement is less than 0.003 in., therefore corresponding flexure plate movement is proportionally small. Negligible vertical motion of the scale platform results from high lever ratios possible with the flexure plates. At weigh-beam positions above and below balance, a flexure resistance is introduced. It helps the beam reach equilibrium faster, increasing response speed. The flexure plates are plumb when the scale is in balance, therefore the flexure resistance effect is completely cancelled.

PS . . . Developed for automatic net-weighing and batching, scale is for continuous operation at capacity of 40 tons/hr at accuracy of ±0.1%. Maintenance problems are reduced—pivotless scale is unaffected by dust, dirt or moisture. In case of damage, flexure plates can be easily replaced by plant maintenance personnel without affecting accuracy. Scale was developed and produced by Thayer Scale Corp, Pembroke, Mass.—J J Kelleher

TOMORROW'S POWER SOURCES —

— AN ENGINEER'S NOTEBOOK OF FACT, IDEA, & SPECULATION

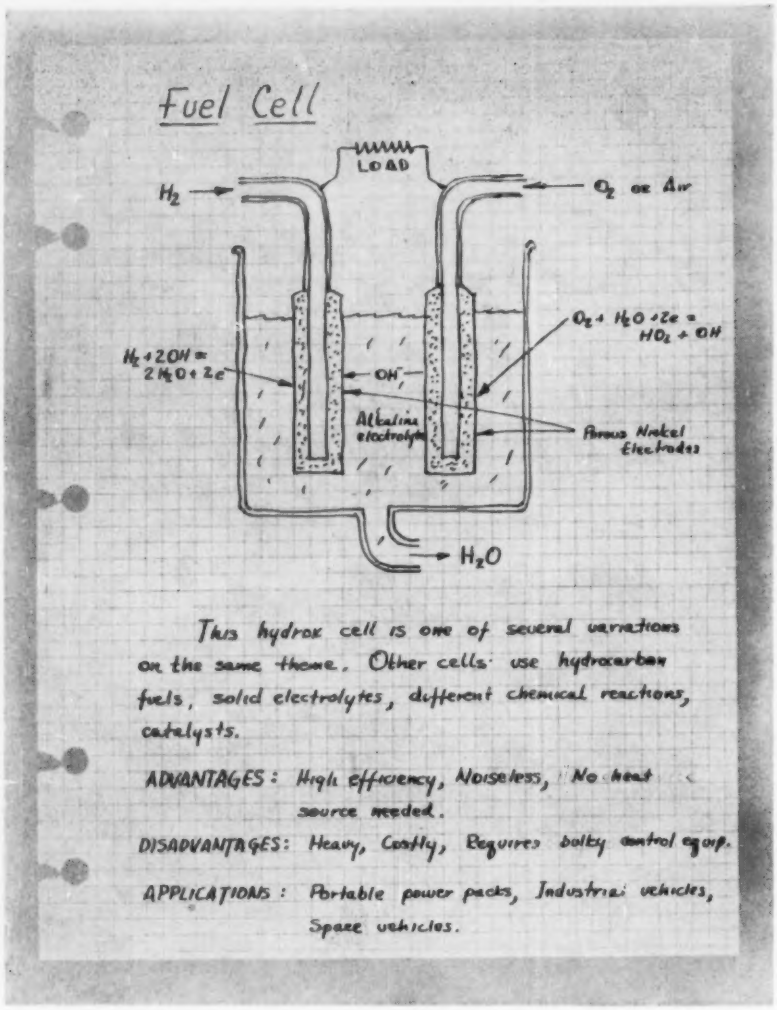
ROY KAMO, Senior Engineer
ARMOUR RESEARCH FOUNDATION

Here's a survey of 14 basic power sources. If you're planning a portable machine requiring from 1 to 500 hp, chances are your choice will be limited to one of these.

■ Even if our achievements in space technology have no other effect on you, they have brought one important byproduct: a variety of new and significant power sources. Where 10 years ago there was no practical way to convert heat directly to electricity, today there are three — and all appear to have features competitive with present sources. And where we've been traditionally tied to diesel and gasoline engines for mechanical power, we can now consider the potentialities of rotary, hot-air and free-piston engines.

Significantly, none of the "new" power sources is really new. The thermoelectric generator is based on a phenomenon discovered in 1821. The MHD generator dates back to Michael Faraday, who proposed a scheme to tap power developed as oceans cut the earth's magnetic field. The thermionic generator is simply a refinement of the Edison effect discovered in 1883. Rotary engines have been with us nearly 50 years and fuel cells are at least twice that old. And "newest" of the newcomers, the

REPRINTED—Circle 614, inside back cover


Fuel Cell
LOAD
H_2
O_2 or Air
$O_2 + H_2O + 2e = HO_2 + OH$
$H_2 + 2OH = 2H_2O + 2e$
OH^-
Alkaline electrolyte
Porous Nickel Electrodes
H_2O
This hydrox cell is one of several variations on the same theme. Other cells use hydrocarbon fuels, solid electrolytes, different chemical reactions, catalysts.
ADVANTAGES: High efficiency, Noiseless, No heat source needed.
DISADVANTAGES: Heavy, Costly, Requires bulky control equip.
APPLICATIONS: Portable power packs, Industrial vehicles, Space vehicles.

Stirling engine, dates from a working powerplant first built in 1816.

What is responsible for the sudden interest in all these old ideas? A one-word answer will suffice—materials. With the new materials and recent insights into the physics of solids, many of these once impractical schemes are now a reality. But we need to go even further; we are still operating at the metallurgical limit. Indeed, the eventual success of many new power sources rests on the faith that such improvements in materials will occur.

Choosing the one best power source is now complicated by a variety of factors. Traditionally the choice has been determined by examining such criteria as efficiency, size and weight. In the future, factors like these will have equal importance:

- Freedom from waste products
- Fast start-up time
- Noiselessness
- Reliability
- Long life
- Ease of maintenance
- Lack of moving parts, with their gyroscopic effects and need for lubrication
- Insensitivity to vibration, shock, climatic extremes

And for each of these, there is a power source that scores outstandingly—so much better than traditional devices, in fact, that it may be chosen for that reason alone.

This survey is limited to primary power sources — those that convert some kind of raw energy source (fuel, heat, or sunlight) into usable power (mechanical or electrical). I exclude energy-storage devices such as batteries because, though they are competitive with some of the powerplants mentioned, they do not deliver continuous power. I have also confined my interest to the range between 1 and 500 kw (though some powerplants that may be impractical in this range—MHD generators and Stirling engines—have here been included for comparison). Within these limits are contained the broadest possible variety of powerplants. In fact, it is safe to say that if you are designing a self-contained unit requiring a continuous supply of power, you'll have to choose one of those described below.

SOURCES OF ELECTRICAL POWER

The most revolutionary—and the most publicized—new power generators are the sources of direct electrical power. They eliminate the traditional mechanical steps between heat and electricity. For this reason, they are scheduled to receive the lion's share of research funds—an estimated $55 million to be spent in 1961. It will be split between these five: fuel cells, thermoelectric generators, thermionic converters, MHD generators, solar cells.

Fuel cells

Fundamentally, a fuel cell is no more mysterious than the familiar lead-acid storage battery—but it is a battery in which the chemical reaction that generates the electricity can continue indefinitely. For this to occur, the cell must be continuously supplied with fresh chemicals and the elements of the cell must not be contaminated by the waste products of the reactions.

A broad range of such devices have been made and tested in the past 10 years. The Hydrox cell (sketch on this page) is typical of the operating principles of all fuel cells. But this particular form has three disadvantages: (1) it requires pure hydrogen, an expensive fuel, (2) the electrolyte is gradually poisoned by carbon dioxide and other impurities in the hydrogen and air, and (3) the porous electrodes are troublesome—and unless the flow of gas is carefully controlled, the necessary simultaneous contact between gas, electrolyte and electrode will not be maintained. It is hoped these objections can be overcome with experimental cells now in development. Some of the improved devices use inexpensive hydrocarbon fuels such as propane or coal gas; others have

solid electrolytes of various types, which offer a better reaction surface and cannot be easily contaminated.

If the extent of present research activity is any index, fuel cells are an extremely promising source of power. More than half the funds being invested in new power sources are going into fuel cell research, much of this under sponsorship by the armed forces. Army wants a noiseless, lightweight power pack; Navy wants a silent, fuel-cell powered sub.

As with many of the new direct generators of electricity, efficiency of the fuel cell decreases with increasing power densities. Though efficiencies of 90% have been quoted for cells generating small currents, 50 to 60% is more realistic, with a goal of about 70% within the next few years. Because of this size limitation and the present high cost of fuel and cells, it is not expected that they will compete with central power stations—at least not in the near future. Nevertheless, the present units are practical for delivering small amounts of power, particularly when the other advantages of noiselessness, cleanliness, and compactness are considered.

Some of the remaining problems are:

Reaction rates are low. There are several solutions to this problem: increased electrode surface area, increased temperature and pressure, addition of catalysts—and all are being investigated. At present, it is not certain which effects, or combination of effects, show most promise.

Lifetime is short. Although some cells have operated as long as a year or more, many of the most practical designs have much shorter life. To prevent cell contamination and deterioration of electrodes, new materials and different design configurations will have to be developed.

Better membranes are needed. In one popular type of cell, a membrane between anode and cathode serves as a kind of "solid" electrolyte. But the membranes are expensive to manufacture, difficult to handle and unable to deliver high current densities.

Leakproof containers are needed. For portable power, the liquid electrolyte must be contained in an enclosure designed to eliminate leakage and spillage.

Auxiliary equipment is too bulky. To maintain precise control over the flow of fuel and air, advanced cells require special control equipment. In some cases, these auxiliaries are larger and heavier than the cell itself.

Thermoelectric generator

A heated junction of two dissimilar metals generates an electric current: thermocouples have been proving it for decades. But until recently the amount of current was too small. With new insights into the physics of solids, however, we now have materials that appear to make this power source practical.

Just how practical is still a question. Developmental thermoelectric generators have generated up to 5 kw with efficiency in the neighborhood of 2%. Experimental devices have been made with efficiency up to 15% and it is expected that we will soon stretch this to 20%. The long-term goal is for generators delivering 20,000 kw at 35% efficiency and weighing about 10 lb/kw.

But practicality will require:

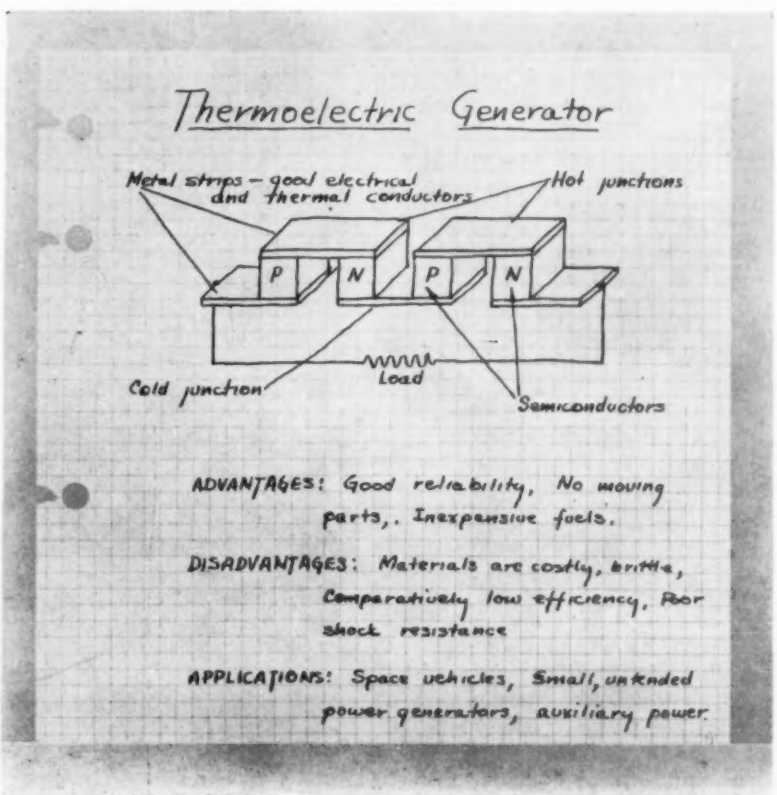
Materials with better electrical properties. Suitability of a material is a function of its figure of merit, Z, generally expressed as

$$Z = \frac{S^2 \sigma}{k}$$

where S is Seebeck coefficient in microvolts/°C $\mu v/c$, σ is electrical conductivity and k is thermal conductivity. The problem is to find a material with high electrical conductivity and low thermal conductivity. This can be arranged in semiconductors by making the electrical conductivity more dependent on lattice vibrations, which do not conduct heat, and less dependent on free electrons, which conduct both heat and electricity. Several semiconductor materials, including compounds of bismuth, lead and tellurium, show progress in this direction.

More efficient configurations. Because figure of merit in most materials has a peak at some specific temperature, researchers have experimented with stacked devices. These combine several different materials, all operating around their peak temperature, to span the thermal bridge between heat source and heat sink.

Materials with better mechanical



properties. Present semiconductor materials are brittle and difficult to shape. They are also expensive—up to $500/lb in some cases.

Improved junction technology. Contact resistance between the thermoelectric material and the electrical lead must be made as small as possible to reduce Joule heating.

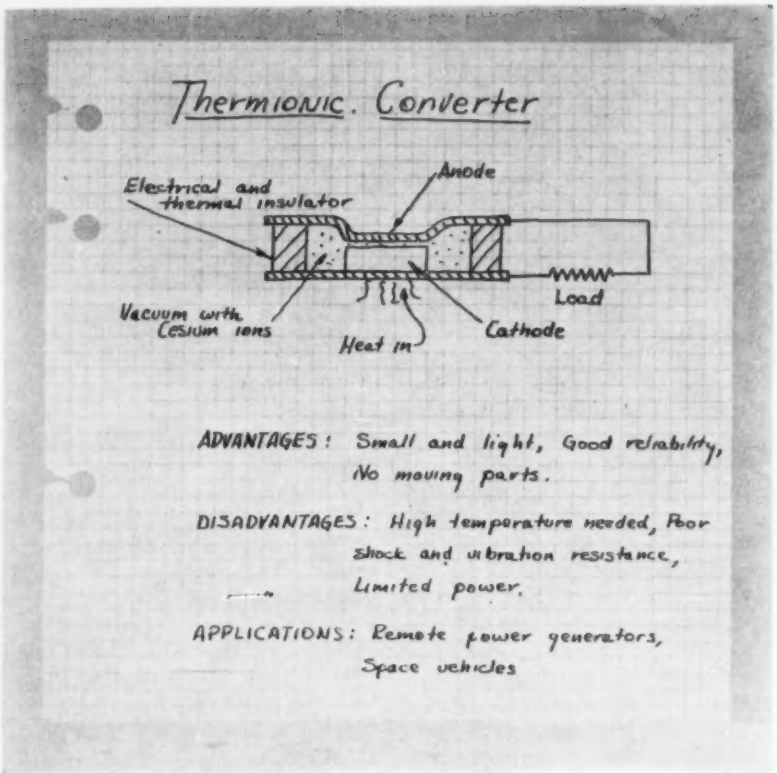
Thermionic converters

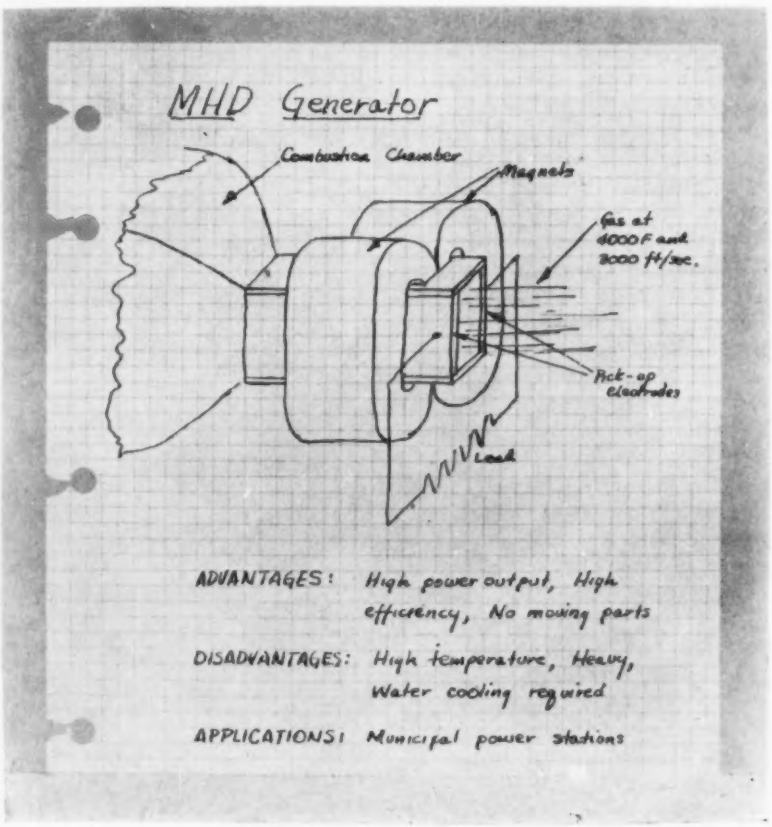
The simplest kind of thermionic converter is an ordinary vacuum diode: when electrons are boiled off the heated cathode their flow to the cooler anode generates a flow of current. Like the thermoelectric device, thermionic converters are low-voltage, high-current generators. Carrying the similarity a step further, a thermionic converter can be likened to a thermoelectric generator with current flow in a gas rather than a solid. And because the gas approaches the ideal thermoelectric material (high electrical conductivity, low thermal conductivity) the theoretical efficiency is higher.

Size and weight can be smaller too. Thermionic devices have been made with power densities of 12.5 lb/kw and 5.5 kw/ft^3—making them attractive for power generation in space vehicles and other portable installations where there is a source of high temperature heat. Experimenters predict capacities of 50 kw and efficiencies of 40%, though 250 w and 14% are about tops at the moment.

Before we can reach these goals here are some of the problems our researchers are being asked to solve:

Space charge barrier. In thermionic devices, as in vacuum tubes, a cloud of emitted electrons forms around the cathode, slowing the electron flow to the anode. At the moment, we are solving this problem in the thermionic converter in the same way we solved it in the vacuum tube: closer spacing between cathode and anode, and injection of an easily ionized vapor. The positive ions of the vapor neutralize the space charge, clearing the path for the emitted electrons. Cesium vapor has been tried in several thermionic devices. It has a low ionization potential (3.88 ev) and is absorbed by the electrodes to reduce their work function. Two other proposed space-charge cancellation methods: (1) ionize the vapor with gamma ray radiation from a nuclear heat source, and


Thermionic Converter
Electrical and thermal insulator
Anode
Load
Vacuum with Cesium ions
Heat in
Cathode
ADVANTAGES: Small and light, Good reliability, No moving parts.
DISADVANTAGES: High temperature needed, Poor shock and vibration resistance, Limited power.
APPLICATIONS: Remote power generators, Space vehicles



(2) place an accelerating electrode between cathode and anode to deflect electrons toward anode.

Better anode and cathode materials. Because voltage output depends on the difference between work functions of cathode and anode, cathode work function should be as high as possible and anode as low as possible. But because the high cathode work function requires a high cathode temperature, part of this heat will be radiated to the anode, reducing efficiency. In addition, the high temperature shortens cathode life. The best materials for high efficiency and long life are still to be found.

Better mechanical configuration and design. The high operating temperatures make design of the gas-enclosing envelope and the electrodes particularly difficult. The leads from the electrode must be large enough to carry the current but not so large that they carry away the heat too. The close tolerance on spacing is also a problem —metals don't want to stay put at 2000 F. And better seals are needed; those adequate for 1000 F (average operating temperature of present devices) are no longer effective at 2000 F.

Comparison of Significant Characteristics

	Power Range, KW (note 1)	Size, ft³/KW	Weight, lb/KW	Max. Thermal Eff.	Status
Fuel Cell	1 - 50 *	2 *	100 *	70% *	Advanced Development
Thermoelectric Generator	0.005 - 50 *	2 *	100 *	20% *	Specialized Production
Thermionic Converter	0.001 - 50 *	0.1 *	1.0 *	30% *	Advanced Development
MHD Generator	(note 2)	0.75 *	100 *	60% *	Development
Solar Cell	0.001 - 1 *	2 *	100 *	15% *	Production
Gasoline Engine - 2-cycle	0.1 - 60	0.02	2.6	16%	Production
Gasoline Engine 4-cycle	0.5 - 500	0.03	2.7	28%	Production
Diesel	40 - 500	0.14	15	25%	Production
Gas Turbine (Regenerative)	50 - 500	0.03	3.0	28%	Production
Free-Piston	180 - 500	0.12	6.5	31%	Limited Production
Rotary Engine	30 - 500	0.02	1.34	27%	Advanced Development
Hot Air (Stirling Engine)	1.5 - 30	0.02	15	33%	Limited Production
Vapor Engine	50 - 500	0.15 (note 3)	5.0 (note 3)	25%	Production
Chemical 'Explosive' Engine	0.1 - 150	0.01	2.0	34%	Limited Production

Notes: * Estimated future capabilities — 5-20 years hence.
1 Limited to 500 KW.
2 Not expected to be competetive in power ratings less than 1000 KW.
3 Including boiler, condenser, and auxilliarys.

MHD generators

For large blocs of power, such as produced by a central power station, the magnetohydrodynamic generator seems to show most promise. The principle is simple enough: a gas made conductive by partial ionization is forced to cut a magnetic field in the same way copper coils cut a conventional generator's magnetic field. The basic generator consists of a gas flow channel bounded on two sides by magnetic poles and on the other two by electrodes that draw off the induced currents.

Unlike other new power sources, the efficiency of an MHD device increases with size. Generators of 1000 kw and larger are expected to show efficiency up to 60% in packages much smaller and lighter than any present generator. And with no moving parts, there should be very little problem with reliability.

But for all its simplicity, many problems remain:

High-temperature materials. Key to the high conversion efficiency are the extremely high operating temperatures and gas velocities. But few engineering materials will withstand 5000-F gas moving at 3000 fps. Large power generators have been built, but because of the temperature limitations they generate power for only a few seconds, or minutes, at most. The recently completed Avco MHD unit produces 205 kw (eventual goal for this unit: 500 kw) but for periods no longer than one minute.

Several possible approaches remain to combat this temperature problem. Most obvious: development of new high-temperature materials. Another way is to "seed" the gas with an easily ionized material such as potassium or cesium to permit conduction at lower temperature. Watercooled electrodes are used but the rate of heat transfer is too low to be very effective. A cushion of cool air flowing between the electrode and the hot gas is effective but reduces electrical conductivity.

Utilization of waste heat. Gas exhausts from the MHD unit at about 4000 F. For best efficiency this waste heat must be put to work. For this reason, the MHD generator is considered by many as simply a "topping unit" for a conventional steam generator. In this scheme, the exhaust heat would be fed to a boiler and the steam used to turn a conventional turbo-generator. Under these conditions it is expected the MHD generator would supply about 50% of the power while the steam plant supplied the remainder.

Conversion to ac power. If the MHD unit is to generate central station power, a way must be found to convert the dc power to ac. Several methods have been suggested: varying

the magnetic field, pulsing the flow or moving the electrodes relative to one another. Or the power could be fed through a dc-ac inverter. But none of these is entirely satisfactory and more research needs to be done.

• **High-temperature heat exchangers needed.** Ideally some of the exhaust heat should be fed back to heat the combustor inlet air. But heat exchangers for these temperatures are difficult to design. One proposal: a pebble-bed heat exchanger in which the exhaust heats a mass of material with a high specific heat and the material is used, in turn, to heat inlet air.

Solar cells

Devices that convert light flux directly into electricity are perhaps more advanced, from a commercial point of view. A variety of cells are now available from a number of manufacturers. They have been used for generating power in space, for powering untended electronic equipment and as power for portable radios.

A typical cell 1 cm square delivers about 40 ma at 0.5 volts for a total output of 8 mw. Assuming an average input power from the sun of 100 mw/cm², the efficiency of this typical unit is 8%. Somewhat better efficiency is possible but 15% is about the limit of the best laboratory devices at the moment. However, efficiency rating of solar cells does not have the same significance as with other power sources because the power is "free." But sun power is also limited--a 100% efficient cell could deliver only 100 mw/cm² on the surface of the earth. So the effort to develop more efficient solar converters is an effort to make better use of the collector surface, not to reduce operating cost.

For wide commercial application, more research will be needed in these areas.

Efficiency. Five years ago, the maximum was from 4 to 6%; today, efficiencies up to 20% are promised within the next five years. Gains will come with development of better materials and with new arrangements and configurations.

Temperature effects. Open circuit voltage falls off rapidly with increasing temperature. This limits present silicon devices to an operating temperature of about 85 F with open circuit voltage falling about 50% at 300 F.

Spark Ignition Engine

ADVANTAGES: Low cost, Reliable, Thoroughly proven

DISADVANTAGES: Complicated mechanism, Low efficiency

APPLICATIONS: Automotive, Marine, Portable machinery

Diesel

ADVANTAGES: High efficiency, Long life, Low fuel cost

DISADVANTAGES: Hard starting, Heavy, Higher cost

APPLICATIONS: Industrial, Tractors, Marine, Automotive

Gas Turbine

ADVANTAGES: Small number of moving parts, Good low-speed torque, Lightweight

DISADVANTAGES: Low efficiency, Noisy, Poor speed control

APPLICATIONS: Auxiliary power, Aircraft, Portable machinery, Off-the-road equipment

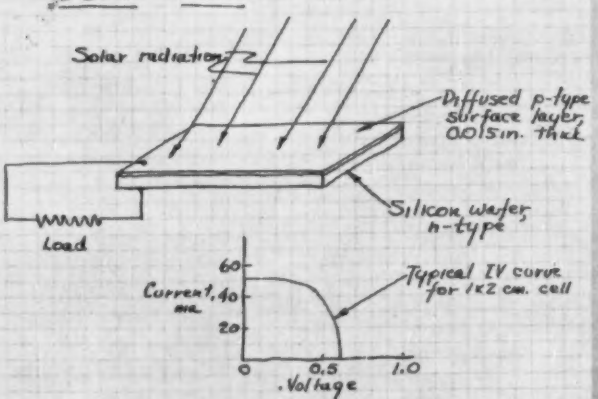
Vapor Engine

ADVANTAGES: Good low-speed torque, Good efficiency Inexpensive fuels, Quiet

DISADVANTAGES: Bulky, Heavy, Slow starting

APPLICATIONS: Large stationary power, Nuclear power plants

Solar Cell



ADVANTAGES: No waste products, Noiseless, Good reliability.

DISADVANTAGES: Limited power, Expensive materials, Poor Efficiency.

APPLICATIONS: Household power in remote areas, Space vehicles, Untended power generators.

Cost. Present commercial devices are much too expensive for most applications. A typical 1x2-cm unit costs about $7.50. Cheaper and simpler assembly methods will lead the way to lower cost solar conversion.

SOURCES OF MECHANICAL POWER

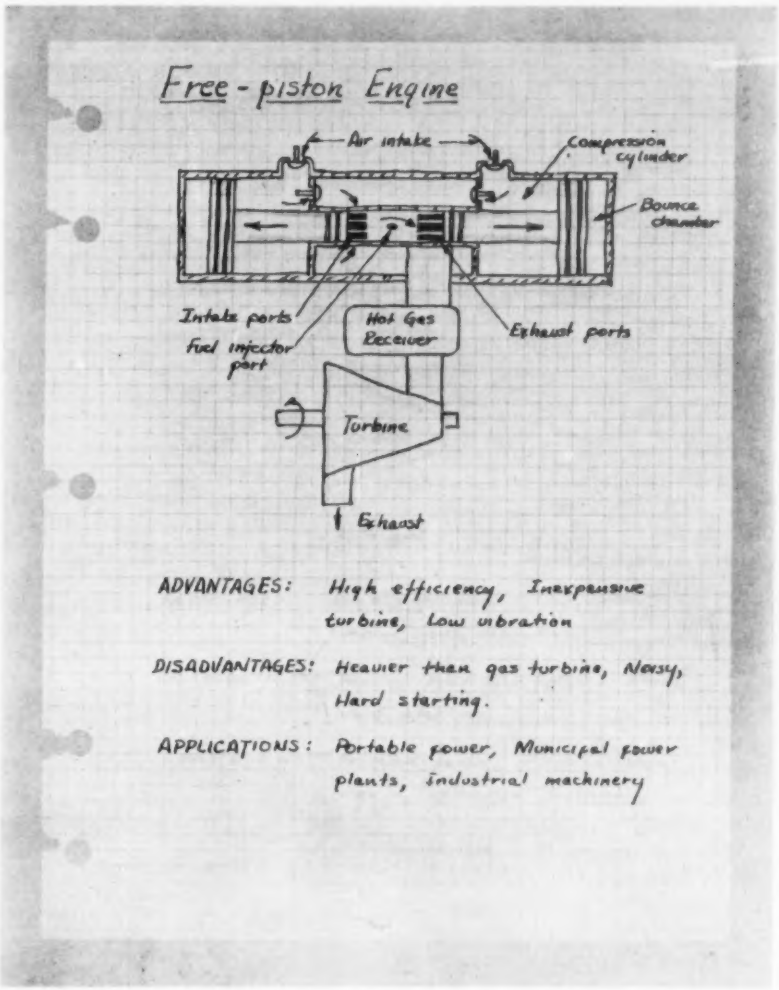
In this category are the familiar powerplants, along with some newcomers. Though most of the newcomers are still experimental, some encouraging tests are being made: NSU has been operating a rotary engine-powered automobile during the last year and Chrysler engineers have been driving a turbine-powered car for more than two years. SIGMA Society in France has two large (over 25,000 kw) free-piston powerplants under construction and GM is making an evaluation study of engines operating on the Stirling cycle. Whether these will replace, or even compete with, our present sources of mechanical power remains to be seen.

Spark-ignition IC engines

This is still the most popular powerplant in the range of 1 to 500 hp and likely to remain so for some years. In the low-power range (1 to 5 hp) the 2-cycle, aircooled engine is most common. Here, its advantages of simplicity, light weight, and low initial cost are of primary importance. But its two disadvantages, poor idle and high operating cost, make it less attractive in the middle and upper power ranges. The high operating cost is a function of two factors: high specific fuel consumption—about 20 to 50% higher than an equivalent 4-cycle engine—and high oil consumption, because oil is usually burned with the fuel in a ratio of about 16:1.

Despite its complicated valves and valve train, the watercooled 4-cycle engine has been developed into a reliable, proven powerplant needing little maintenance. It has the further advantages of low specific fuel consumption and smooth operation over a wide range of power settings. The current trend is to overhead valves (which give improved volumetric efficiency) and bore-to-stroke ratios greater than 1.0. The large bore gives superior breathing, the short stroke reduces the frictional load and the rate of heat rejection to the cooling system.

Aircooled 4-cycle engines, though now restricted to the range between 1 and 25 hp (except for automotive and aircraft engines), are beginning to appear as a serious challenge to liquid-cooled engines in all power ranges. The aircooled engines are easier to operate and maintain under all climatic conditions, and can reach stable operating temperature, from cold, in less than 5 sec, a feature which reduces wear and inhibits formation of harmful acids in lubricating oil.



Diesel engines

Perhaps the sole justification for the compression-ignition engine is its lower specific fuel consumption at all loads. Other advantages: broader torque curve, longer engine life, less maintenance, and ease of supercharging without detonation problems. Disadvantages: greater weight, slower speed, higher initial cost, harder starting, more vibration and noise.

Four-cycle diesels have been common in the past but with the advent of the exhaust turbocharger and an improved scavenging system, the supercharged 2-cycle diesel is gaining favor and appears likely to surpass the best 4-cycle engine in every respect. Supercharging can easily improve engine performance by as much as 35%. Fuel consumption and "smoke" curves do not turn up sharply as they do in naturally aspirated engines because the supercharged engine cannot run out of air. Supercharging also reduces size, weight and initial cost for a given horsepower and makes the design simpler and more reliable. Aircooled diesels are becoming more popular, particularly in Europe for the same reasons cited for spark-ignition engines: less wear, faster warm-up, reduced complexity.

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Gas turbines

With the steady improvement of gas turbines over the last 10 years, an increasing number of applications have appeared to capitalize on this powerplant's unique advantages. A chief advantage is its simplicity. A gas turbine has only about 10% as many parts as a reciprocating engine. Elaborate lubricating systems are not needed because all major ball and roller bearings are aligned along one shaft. The ignition system, used only at start-up, can be reduced to a few rudimentary parts. And aircooling eliminates radiator, hoses, thermostats and their problems. Because of this simplicity, maintenance and construction costs are lower, reliability is higher, and required spare-parts inventory is much reduced.

Another advantage is its peculiar (in comparison to reciprocating engines) torque-speed characteristic—torque is maximum at stall and falls off with increasing speed (assuming a turbine in which compressor and power turbine are on separate shafts). This gives high starting torque and assures an increase in torque when speed drops with increased load.

Other advantages: It is small (and usually lightweight) with volume about ⅓ of comparable gasoline engine and ⅛ of comparable diesel. It is smooth and vibrationless because there are no reciprocating parts. Moreover, it gives maximum fuel economy at maximum load.

But this fuel-economy feature works both ways, contributing to its biggest disadvantage: high fuel consumption at partial load. Present thermal efficiency of small, non-regenerative gas turbines is only about 13%. Turbine engineers anticipate this will be improved in future turbines and point to four avenues of approach.

Improve compressor and turbine efficiency. A 1% increase in compressor efficiency will give a 0.3% gain in thermal efficiency and a 1% increase in turbine efficiency will give a 0.5% gain.

Increase combustion temperature. This will increase both thermal efficiency and power output but is presently limited by metallurgical considerations.

Increase pressure ratio. At 1500 F combustion temperature, a change in pressure ratio from 4:1 to 8:1 will increase thermal efficiency from 19% to 26%.

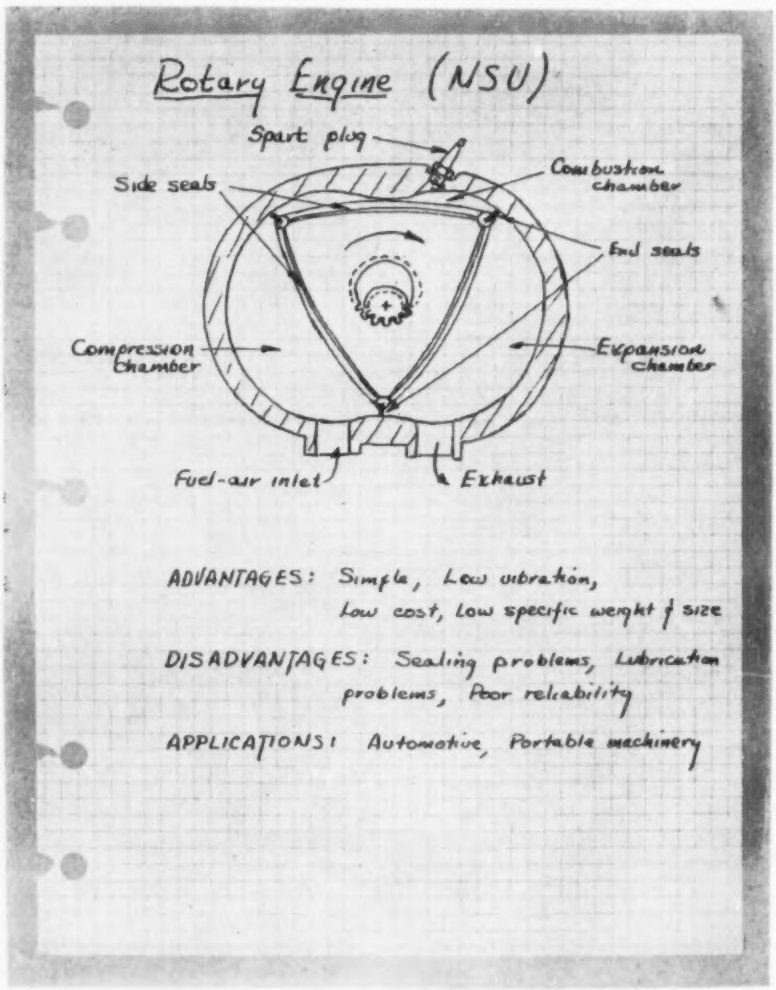
Add regenerator. For a turbine operating at 1500 F and 4.1 pressure ratio, 60% regeneration will boost efficiency from 19 to 28%, and 90% regeneration will boost it to 35%.

Besides low efficiency, there are other problems. Turbine wheels are expensive to manufacture and are the parts most likely to fail. Power output is closely linked to temperature of inlet air—more closely linked than with reciprocating engines because of the large quantities of air consumed (about 0.022 lb/hp compared with 0.002 lb/hp for piston engines). As inlet temperature increases, power output decreases sharply.

High turbine speeds are also a disadvantage. In most cases, gearboxes are required to reduce the rpm to a usable value. Noise is also a problem, primarily because the high-frequency "whine" has a higher annoyance factor than piston-engine exhaust noise. But this high-pitched whistle is easier to silence than the pulsating explosions of a piston engine, particularly in stationary powerplants where acoustically lined intake and exhaust ducts can be provided.

Free-piston engine

The free-piston engine is a cross between an opposed-piston diesel engine and a gas turbine, with some advantages and disadvantages of each. Like the diesel, it has two reciprocating pistons working in opposite directions in the same cylinder, with the combustion chamber between. But in the free-piston design, pistons are driven apart by combustion of the fuel and returned to compress the next



charge by gas pressure in the bounce chambers at both ends of the gasifier. They are not coupled to a mechanical output; they serve only to compress and ignite the gas for subsequent expansion in a turbine.

This arrangement has some advantages of its own. Friction is greatly reduced with the bearings and piston thrust forces. And compression pressures can be higher than those permitted by today's bearing materials. This allows a high pressure ratio, on the order of 50:1, which results in a very high over-all thermal efficiency: 37% was recently reported for a French powerplant.

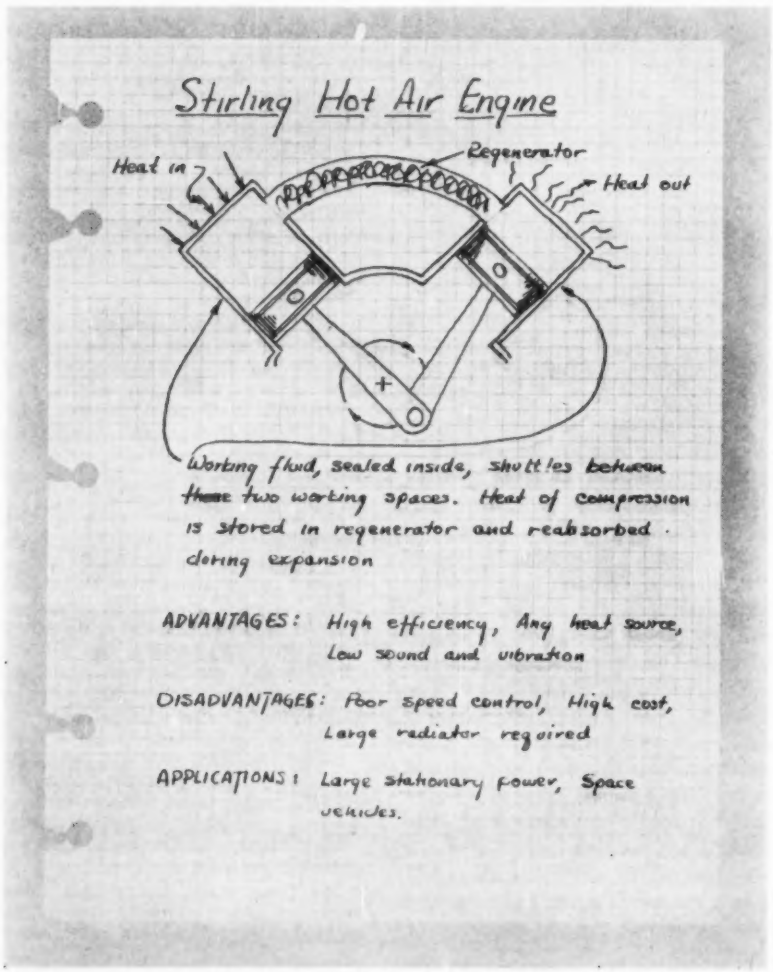
In free-piston engines, the amount of air drawn into the intakes of the gasifier is at least three times that needed for complete combustion of the fuel. Result: a cooler turbine-inlet temperature and a turbine wheel made of less expensive and more readily available materials.

Though heavier than a comparable gas turbine, it retains many of the advantages of the turbine simplicity and torque-speed characteristics. Because the reciprocating pistons can be balanced by merely keeping their weights equal, vibration level is also very low.

Rotary engine

Another new type, this time combining features of the turbine and the spark-ignition engine, is the rotary engine. Like the piston engine, it operates on a constant-volume cycle and power is generated in pulses. It offers attractive possibilities because of its simplicity, low cost, freedom from vibration, small weight and bulk, and elimination of speed-restricting valve gear mechanism. But there are obstacles to its reaching full commercial development. The first major problem is to find a cycle and configuration of rotor and combustion chamber that will give suitable power output. The second, related to the first, is to provide sufficient port areas and appropriate timing for best thermodynamic efficiency. The third is to find a suitable way to seal and lubricate the high-pressure chambers in several planes.

The most recent attempt to solve these problems was announced with introduction of the much publicized German NSU rotary engine. It has a three-lobe rotor spinning in an egg-shape chamber to give three power pulses per revolution. Seals are spring-loaded vanes retained in slots on sides and tops of rotor. Though detailed information is scarce, NSU engineers claim an output of 1.67 hp/in^3 displacement, specific fuel consumption of 0.47 lb/hp-hr, and flat torque curve over a 2000 to 6000 rpm range for their 100-hp engine.


Stirling Hot Air Engine
Heat in
Regenerator
Heat out
Working fluid, sealed inside, shuttles between these two working spaces. Heat of compression is stored in regenerator and reabsorbed during expansion
ADVANTAGES: High efficiency, Any heat source, Low sound and vibration
DISADVANTAGES: Poor speed control, High cost, Large radiator required
APPLICATIONS: Large stationary power, Space vehicles.

Stirling regenerative engine

One of the oldest thermal machines has recently been resurrected and now shows promise of competing with other powerplants. The Stirling engine (see cover of this issue) is an **external** combustion engine. The working fluid is sealed within the engine and receives its heat from any convenient high-temperature external heat source (the sun, in the case of our cover engine).

The Stirling engine has high thermal efficiency (approaching the ideal Carnot efficiency) because the cycle is regenerative. With the working fluid sealed inside, the heat of compression can be stored and reabsorbed during expansion. Efficiencies up to 39% have been reported. Other advantages are low sound and vibration levels, and good power-to-weight and power-to-displacement ratios. Disadvantages are high cost and the difficulty of throttling the power.

Philips Research Laboratories of Eindhoven, Netherlands (with recent interest and cooperation from General Motors in this country) has spent nearly 20 years in research and development of a successful Stirling engine. Though the results are promising, it appears at present to have more future as a large stationary powerplant than as a portable engine.

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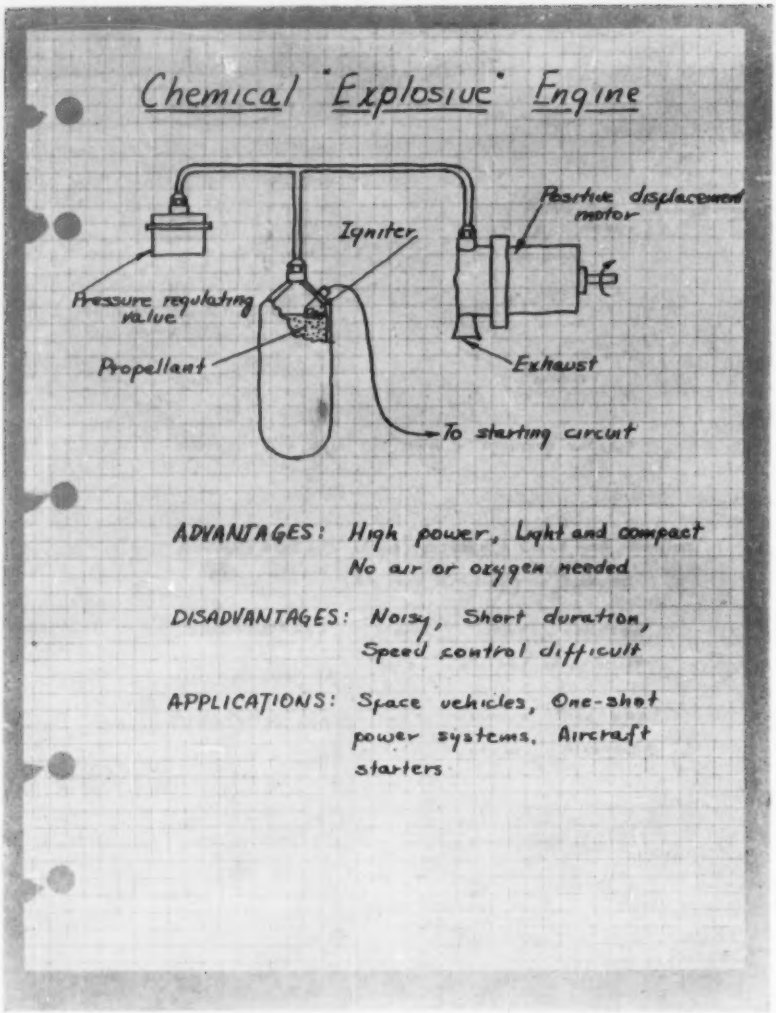

Vapor engines

Even the oldest of our heat power (steam) engines shows no sign of being replaced; nuclear powered steam engines may be used for auxiliary power in space. New materials and new heat sources are responsible for steady improvement in all types of vapor engines.

The choice of engine type and work-fluid depends primarily on the horsepower required and operating temperature. Positive-displacement reciprocating engines are usually chosen for power outputs of less than 20 hp. In this range, piston-engine efficiency is about 75%, compared with about 45% for small turbines. Only a few working fluids have the necessary thermodynamic and mechanical properties. The choice is chiefly limited to three: water, mercury and some Freon groups. Water, of course, is the most common but for high-temperature operation, mercury has a number of important advantages whereas for low temperatures Freon has the advantage. But mercury and Freon must be operated on a closed cycle requiring a condenser and heavy, bulky auxiliaries.

Two small, self-contained vapor-cycle turbine engines have recently been developed for possible application as power generators in space vehicles. The two powerplants, designated SNAP I and SNAP II (for "Systems for Nuclear Auxiliary Power") deliver 0.5 and 3 kw respectively. Both use mercury as the working fluid and have a small reactor to supply boiler heat. Though not completed, the SNAP II system—less its reactor shield—is expected to weigh less than 620 lb in a volume of about 110 cu ft and have an over-all thermal efficiency of about 10%.

Chemical "explosive" engine

Though the number of applications are limited, a turbine or positive-displacement engine driven by combustion gases from a burning propellant has some advantages when a compact power source is needed for short durations. Propellants can be of three types: solid, liquid bi-propellant or liquid monopropellant. The solid propellant is simplest and most reliable, but cannot be throttled for variations in load. The fluid propellants can be throttled but require complex fuel-flow devices.

Positive-displacement engines of either the piston or rotating-vane variety are most efficient for low-speed and low-power ranges but are difficult to lubricate at high temperatures. Turbines are more simple and reliable but are inefficient because of the small arc of admission necessary to operate at low power levels. Biggest disadvantage of the chemical engine, besides its short-term power cycle, is the need to supply both fuel and oxidizer—an undesirable weight penalty. ■

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EDITOR'S NOTE: For previous articles on these and other power sources, see:

TAMING TOMORROW'S POWER SOURCES, May 4 '59, p 28—A rundown on some of the most promising methods for producing power, including nuclear fission and fusion.

HIGHER-ENERGY BATTERIES, May 25 '59, p. 46—A look at what the future promises in the way of batteries made of high-energy electrode pairs.

WET-CELL BATTERIES FOR POWER Feb 15 '60, p 75—Comparison of rechargeable wet cell batteries: lead-acid, nickel-iron, nickel-cadmium, silver-zinc, and silver cadmium.

ATOMIC ENERGY: THE FACTS, Apr 14 '58, p 52—Reviews atomic energy's potential as a power source. Some of the promises have since been filled, others still await development.

EXPLOSIVES BECOME PORTABLE POWER PACKS, Jan 6 '58, p 56—How you can use rocket-powered and powder-actuated energy sources, with some commercial examples.

THESE 3 STEPS CHOOSE A BATTERY-POWERED MOTOR, Oct 12 '59, p 62—The steps you must take to match a motor to its battery—with an electric automobile as the example.

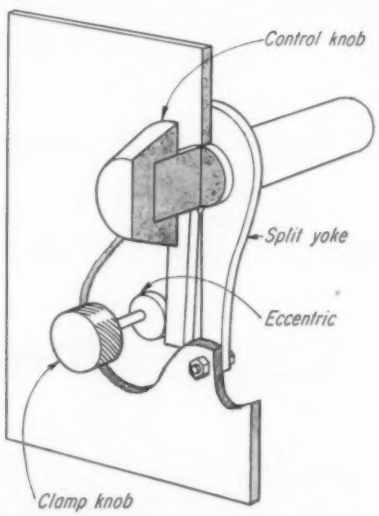
THE SMALL GAS TURBINE—CANDIDATE FOR ECONOMY, Aug 4 '58, p 38—These small, lightweight power packages can rival the diesel in fuel cost when exhaust heat it put to work.

—Charles J Lynch

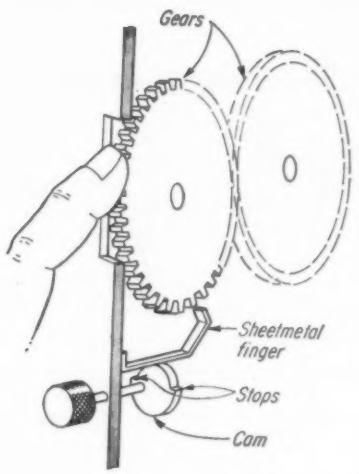
CONTROL-LOCKS THWART VIBRATION AND SHOCK

Critical adjustments stay put—safe against accidental turning or deliberate fiddling with them.

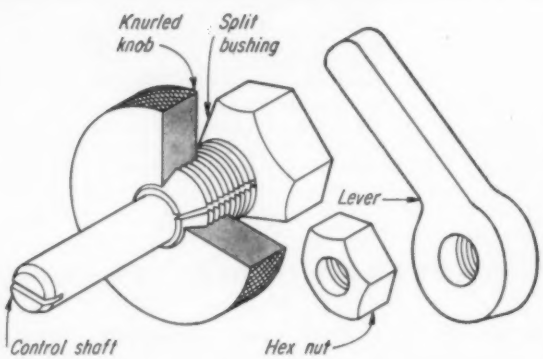
FRANK WILLIAM WOOD JR
President, Advanced Designs Inc
Vienna, Va



1.. SPLIT YOKE clamps on shaft when eccentric squeezes ends of yoke together. Knurled knob is handy for constant use, and eliminates need for tool. Another advantage is high torque capacity. But this design needs considerable space on panel.

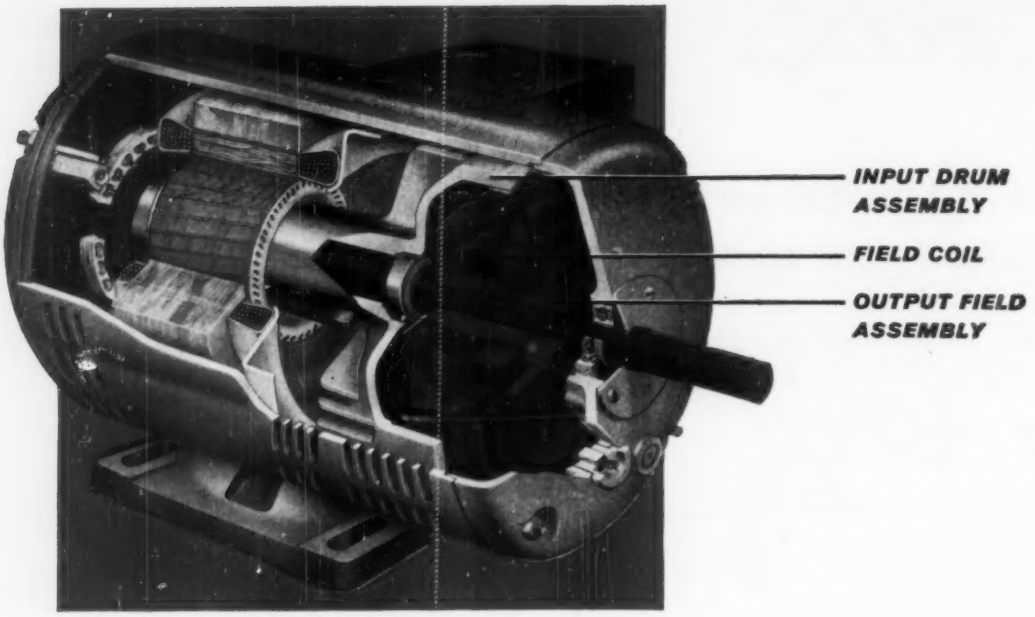


2.. FINGER springs into place between gear teeth at turn of cam. Although gear lock is ideally suited for right-angle drives, size of teeth limits positioning accuracy.



3.. SPLIT BUSHING tightens on control shaft, because knurled knob has tapered thread. Bushing also mounts control to panel, so requires just one hole. Lever, like knob, does away with tools, but locks tighter and faster. For controls adjusted infrequently, hex nut turns a fault into an advantage. Although it takes a wrench to turn the nut, added difficulty guards against knob-twisters.

continued, page 63



Get Stepless Adjustable Speed from AC Power

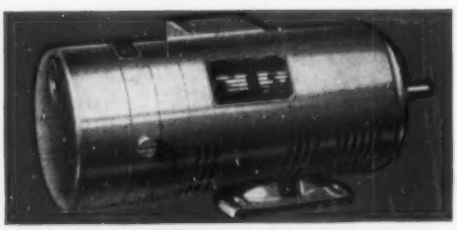
with DYNAMATIC Fractional HP Ajusto-Spede® Drives

Wherever infinite adjustment and accurate control of speeds are required, Eaton-Dynamatic Ajusto-Spede Drives offer a simple, low-cost solution to the problem—stepless adjustment from zero to full output speed, and accurate control of any speed within the speed range.

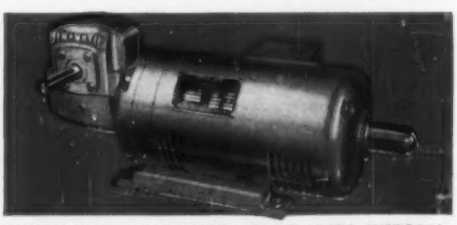
The Dynamatic Ajusto-Spede Drive is an integral combination of AC constant speed induction motor, eddy-current coupling, and plug-in type single-tube electronic control. Torque developed in the motor is transmitted to the driven member by electro-magnetic attraction; there is no mechanical contact between the driving and driven members.

Dynamatic Ajusto-Spede Drives operate on standard 115/230 volt, single phase, 60 cycle or 220/440 volt, 3 phase, 60 cycle alternating current—no special power source is required. Sizes are ¼, ½, and ¾ horsepower at 1600 RPM; ½, ¾, and 1 horsepower at 3200 RPM.

With standard, special, or remotely mounted transistorized control, Dynamatic Ajusto-Spede Drives offer many worthwhile advantages not found in other methods of speed control. Send for illustrated descriptive literature.



DYNAMATIC AJUSTO-SPEDE DRIVE WITH ELECTRICALLY OPERATED BRAKE. With the safety type friction brake, it is possible to achieve rapid deceleration and quick stop, thus providing fast cycling operation.



DYNAMATIC AJUSTO-SPEDE DRIVE WITH INTEGRAL SPEED REDUCER. Because of the variety of gear ratios available in the reducer, this compact assembly is adaptable to a wide range of slow speed applications.

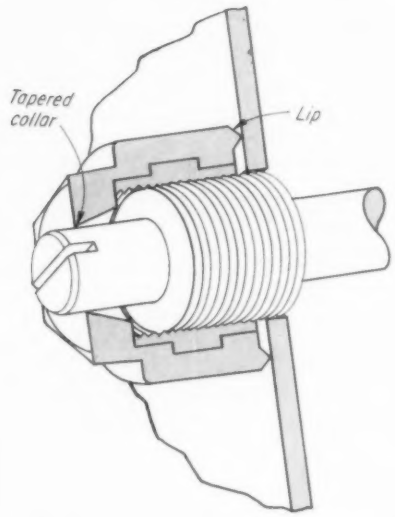
EATON

DYNAMATIC DIVISION

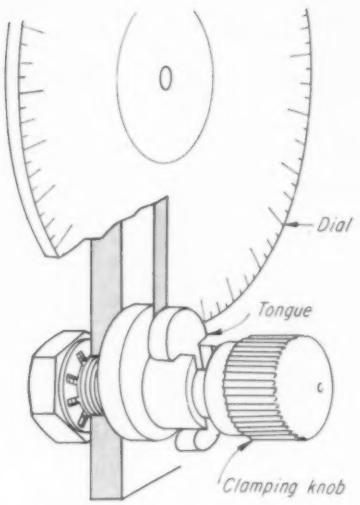
3122 FOURTEENTH AVENUE • KENOSHA, WISCONSIN

ORIGINATORS OF EDDY-CURRENT SPEED CONTROL EQUIPMENT

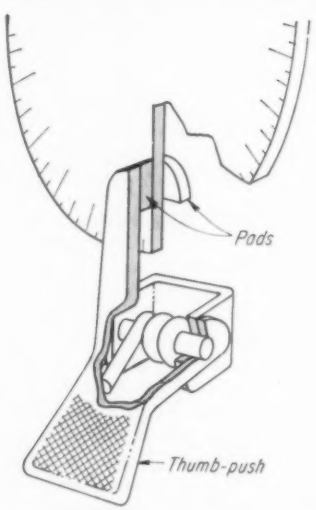
CONTROL-LOCKS THWART VIBRATION AND SHOCK continued



4..CONSTANT DRAG of tapered collar on shaft makes control stiff, so it doesn't need locking and unlocking. Compressed lip both seals out dust and keeps molded locking nut from rotating.



5..TONGUE slides in groove, clamps down on edge of dial. If clamp is not tight, it can scratch the face.



6..SPOT-BRAKE clamp is self-locking, which means it takes two hands to make an adjustment, one to hold the clamp open and one to turn the dial.

SIGNIFICANT COMPONENTS MATERIALS, PROCESSES

Cylinder stroke is programmed . . .

as to length and speed by integral transducer which produces output voltage proportional to piston position. Electrical signals can be recorded, and, on command, used to drive cylinder in repetitive operations. Transducer is pressure balanced and said to be unaffected by cylinder rotation or axis orientation. Unit normally is employed in a closed loop hydraulic circuit using servovalves and can be mounted either singly or in multiples to obtain any desired work position. Automates such repetitive manual operations as press feeding, parts removal, clamping, turning, indexing, assembly and disassembly, machine tool actuation, etc. Output signal also can be used for controlling remotely installed cylinders which actuate dampers, chutes, rolls, charging loads, levers and other mechanical devices. Available in bore sizes to 6 in.; strokes to 50 in.; pressure to 1000 psi; and output to 10 v. Priced at approx $1000. Delivery in 3 to 4 wk. **Guerin Engineering Inc, 23255 Woodward Ave, Ferndale 20, Mich.**

Circle 300 on Reader Service Card

High-strength film adhesive

can be cured under pressures of 10 to 25 psi for metal-to-metal bonding and metal honeycomb sandwich construction. Normally, film adhesives require an optimum curing pressure of from 50 to 150 psi. Provides metal-to-metal shear strengths of 4700 psi at 75 F and over 4000 psi at 180 F. When properly cured, adhesive is said to have excellent resistance to vibration and shock and to resist water, oils, fuels and salt spray. Can be "heat tacked" to metal surfaces and reportedly is highly conformable. Recommended cure time for bonding at 350 F is 60 min. However, in metal-to-metal bonding, cures can be accomplished in 1 min. at 450 F with a resulting shear strength of 2600 psi at 75 F service temp. **Adhesives, Coating & Sealers Div, Minnesota Mining & Mfg Co, 900 Bush Ave, St Paul, Minn.**

Circle 301 on Reader Service Card

Epoxy-finished aluminum sheet

provides anodized-bright appearances in interior trim applications. Finish is technique for applying paint to aluminum which retains most of metal's reflective luster. Available in 0.012 and 0.040 in.-thick, 12 to 18 in.-wide, plain one-side bright and embossed pattern sheets. Plain one-side bright sheet is priced at 69.4¢ per lb in 0.012-in. thickness and 53.6¢ per lb in 0.040-in. thickness. Embossed sheet is priced at 71.7¢ per lb in 0.012-in. thickness and 55¢ per lb in 0.040-in. thickness. Commercially available Aug 1, with delivery in 6 wk. **Reynolds Metals Co, Richmond, Va.**

Circle 302 on Reader Service Card

Surge-proof checkvalve . . .

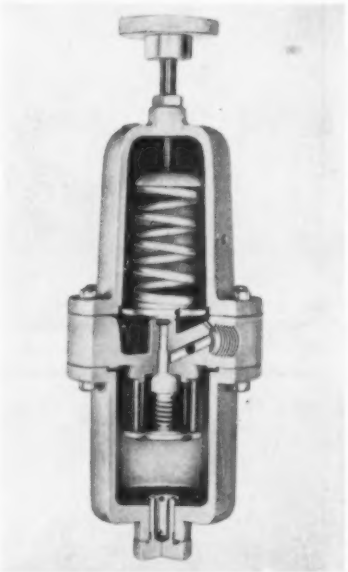
operates at pressures of 3000 psi and up, with 10-psi pressure drop at rated flow. Hydraulic deceleration device eliminates surge shock, while knife-edge, metal-to-metal valve seat is said to perform to military specifications. Has one-piece body with no gaskets to loosen or leak. Operating temp ranges from −250 to 500 F. From stock in ¾- to 1-in. sizes. **Bruning Co, Lincoln, Neb.**

Circle 303 on Reader Service Card

Snap blade circuit breaker . . .

protects against locked rotor and short circuit conditions under specified temperatures. Designed for use in continuously running motors in which ratio between running overload and locked rotor current is small. Also can hold its closed position and permit flow of current even when surrounding temperatures are almost as high as heat generated by an overload. This is said to allow motors to be designed with increased torque. Unit basically is a single bimetal blade anchored to a mounting post at one end and with a pair of fine silver contacts at opposite end. Bimetal blade has two longitudinally parallel slots in its face to control current density and temperature. Under normal conditions, breaker contacts remain in closed position. With initial locked rotor overload heating, center bimetal leg expands and deflects downward, causing silver contacts to snap open. With circuit open, bimetal cools and procedure reverses snapping contacts closed. Breaker cycles indefinitely as long as overload persists. Available in either ac or dc ratings. Dc breakers range from 6 to 24 v and handle locked rotor currents from 10 to 70 amp with trip times from 2 to 20 sec. Typical reset times are from 1 to 6 sec. Ac version handles 115 v nominal voltage and locked rotor current ratings from 15 to 60 amp. **Sylvania Electric Products Inc, Ipswich, Mass.**

Circle 304 on Reader Service Card



Filter-regulator . . .

has one-piece inner valve that provides tight dead-end shutoff and uses a sensitive diaphragm-spring combination to provide a high capacity-to-droop ratio. At 100 psig inlet pressure and 20 psig outlet pressure, its capacity is 14.75 scfm with only a 1-psi droop. Can be used at inlet pressures to 150 psig and is available in four controlled-pressure ranges from 0 to 125 psig. Inner valve is made of Delrin 500, high in tensile strength and resilient enough for a tight-sealing soft seat. Filtration is provided by 40-micron cylin-

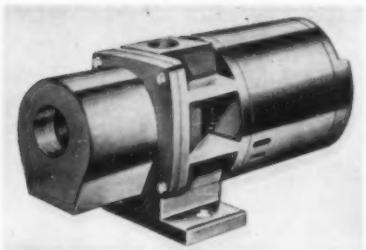
drical filter made of phenolic resin-impregnated cellulose. Filter is said to be unaffected by contaminants common to pneumatic systems and is accessible by removing dripwell bowl. **Kieley & Mueller Inc, 64 Genung St, Middletown, NY.**

Circle 305 on Reader Service Card

Time relays . . .

are transistor-equipped. Different models function as "on time delay," "off time delay," or "interval timer" with instantaneous reset action. Operate from ac or dc voltages and are voltage- and pulse-stabilized. Timing periods are available from seconds to over 1½ hr; timing accuracy, ±5%. Temp ranges to 149 F. Available as surface or flush panel mounted units, they have 5 amp, 3PDT contacts, eliminating auxiliary relays. Output can be either solid state or relay. Prices are said to range from 30% to 90% below similar units. **Clearview Electronics Corp Inc, PO Box 294, Elkton, Md.**

Circle 306 on Reader Service Card



Multistage centrifugal pump

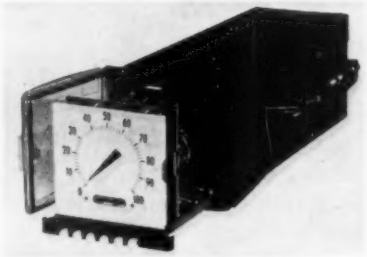
for flows to 40 gpm, has net positive suction head of less than 1 ft, allowing pump to handle highly volatile liquids that are near flash point without danger of cavitation. Multistage design allows unit to develop higher heads with less hp than conventional centrifugal pumps. Smaller sizes, with flow rates to 25 gpm, are standard with machined brass or Delrin impeller and diffuser. Larger sizes have machined brass impeller with cast iron diffuser bowl. All models have fluid bearings at each end of assembly and ⅜-in. seal. Measures from 13 to 20 in. long and 7¼ in. high. **Red Jacket Mfg Co, Industrial Div, Box 270, Davenport, Iowa.**

Circle 307 on Reader Service Card

High-speed tool steel . . .

can be hardened and tempered to 68 Rockwell C, making it suitable for cutting hard or otherwise difficult-to-machine alloys. Has following composition: 1.10% carbon; 4.25% chromium; 6.75% tungsten; 3.75% molybdenum; 2% vanadium; and 5% cobalt. When atmosphere-controlled furnaces are used, preheating range is 1500 to 1550 F and hardening range is 2200 to 2250 F. When salt bath heating is used, hardening range is 2175 to 2225 F. In tests to date, material reportedly has performed as well or better than several high-cobalt and high-vanadium high-speed steels, including more expensive grade with 12% cobalt. **Crucible Steel Co of America, Oliver Bldg, Pittsburgh 22.**

Circle 308 on Reader Service Card



Capacitance-type level indicator . . .

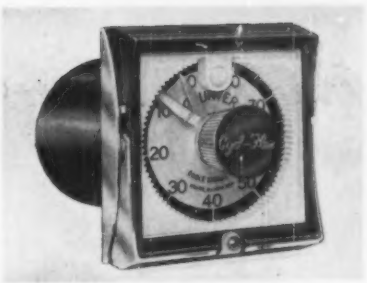
indicates and/or controls signals in a receiver capable of accepting signals from up to 6 different probes. Probes can be located at distances up to 1000 ft from instrument with no need for an intermediate "black box." Receiver, which uses solid state electronic circuits of plug-in design, has accuracy of better than 1%. Circuitry consisting of self-balancing bridge with servo readout to eliminate drift needs only a one-time calibration. Receiver measures 6 x 6 x 16 in., is panel-mounted and operates from 115 v, 60 cps. **Magnetic Instruments Co Inc, Thornwood, NY.**

Circle 309 on Reader Service Card

Continuous-tape reel . . .

plays any one of several messages instantly upon command. Tape is spliced to form one continuous loop, eliminating stop and rewind operations when data or voice messages are to be played over and over. Cartridge holds messages from 10 sec to 3 min. long. Unit supplied with or without electronics. **Metric Processing Corp, 143 Roseland Ave, Caldwell, NJ.**

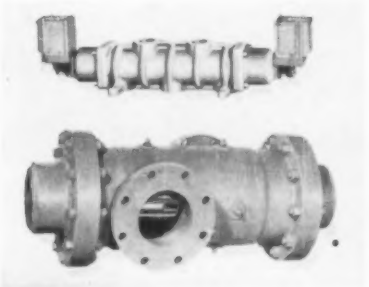
Circle 310 on Reader Service Card



Plug-in impulse counter . . .

is spring-reset to "0", making it suitable for automatic control circuits which must function from counts. Includes two SPDT, 5-amp delayed switches which trip at end of a preset count. Another switch is operated instantly by the clutch coil at beginning of the count. Reset time is ½ sec, accomplished electrically by the clutch solenoid. Max count speed is 400 counts per min.; range, 80 counts. Change of count setting can be made at any time in cycle. When setting is made in reset (or counted out) position, new setting becomes effective at once. Designed primarily for flush mounting, case is installed by cutting one 3½-in. dia opening. Special counters are available for one of the two delayed SPDT switches to trip 1, 2 or 3 counts ahead of max count setting. Operates on 115 v, 60 c. **Eagle Signal Co, 202 20th St, Moline, Ill.**

Circle 311 on Reader Service Card



High-flow air valves . . .

in sizes up to 8 in., are suitable for up to 250-psi service and have capacities of more than 32,000 cfm at 100 psi pressure drop. Eliminate need for multiple valving to meet flow requirements. Hollow ported plunger and U-packer design said to provide max flow, low pressure drop, positive sealing and long service life. Packer design uses pressure loading—higher the pressure, tighter the seal. **Hunt Valve Co, Salem, Ohio.**

Circle 312 on Reader Service Card

Size-5 brakes, clutches . . .

have high torque per watt and "no-creep" design, said to prevent angular displace-

continued on page 68

AT WHIRLPOOL CORPORATION . . .

One Dayton Poly-V® belt spins drum

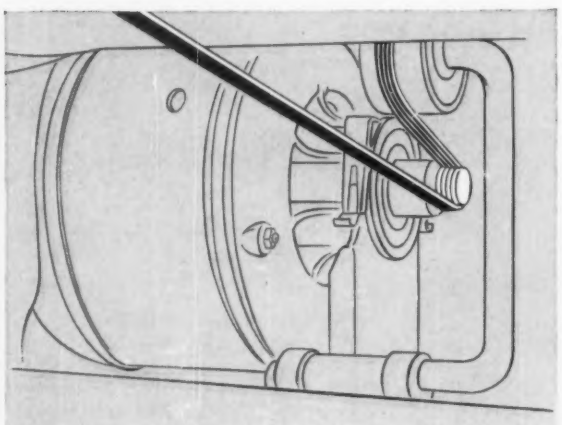
Uses no intermediate reduction stage or drum sheave

There are many interesting design features in the new RCA-Whirlpool Clothes Dryer. One is the drum drive. It consists of a single three-rib Dayton Poly-V belt, driven directly from an 1 1/16" motor sheave to the periphery of a 27¼" dryer drum. No intermediate stages are used to obtain the required 36:1 reduction—and no grooves or guides are used on the drum surface.

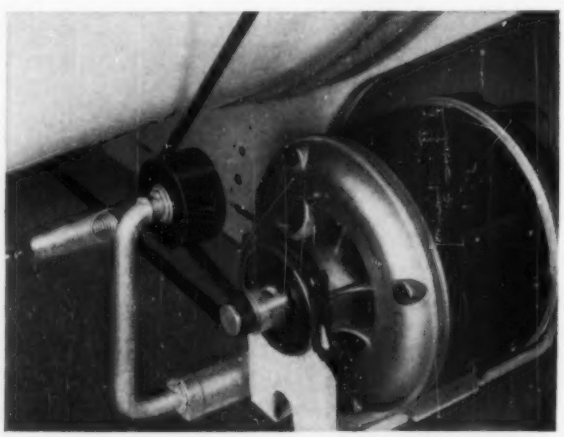
Simplifies Construction. Previous models obtained the 47 RPM drum speed with a two-stage reduction system. By moving the drive load forward on the drum, it was also possible to design a less costly, but equally efficient bearing arrangement. The resulting design simplification has led to important production economies, too.

Tracking an Important Consideration. Whirlpool engineers found that conventional belts tended to "flop over" or jump off the small motor sheave. Thorough testing proved that Poly-V's *full contact design* keeps the belt firmly seated in the sheave and prevents it from "wandering" over the drum surface.

Flexibility Important, Too. Even if the proper sheave wrap-around were possible with conventional belts, constant flexing over the sub-diameter sheave would materially shorten service life. The reduced thickness of the Dayton Poly-V belt gives it greater flex life—lengthens drive life, reduces internal heat build up, and assures user satisfaction.



The new Dayton Poly-V employs a single parallel V-ribbed belt running in sheaves designed to mate precisely with belt ribs. Single unit design provides twice the tractive surface per inch of sheave width—up to 50% more power in as little as ⅔ the space.



Poly-V's reduced belt thickness means smaller sheave diameters can be used. Result: less centrifugal force, permitting operation at higher belt speeds.

®Registered trademark of R/M Inc. Manufactured by Dayco Corp. under exclusive license of Raybestos-Manhattan, Inc.

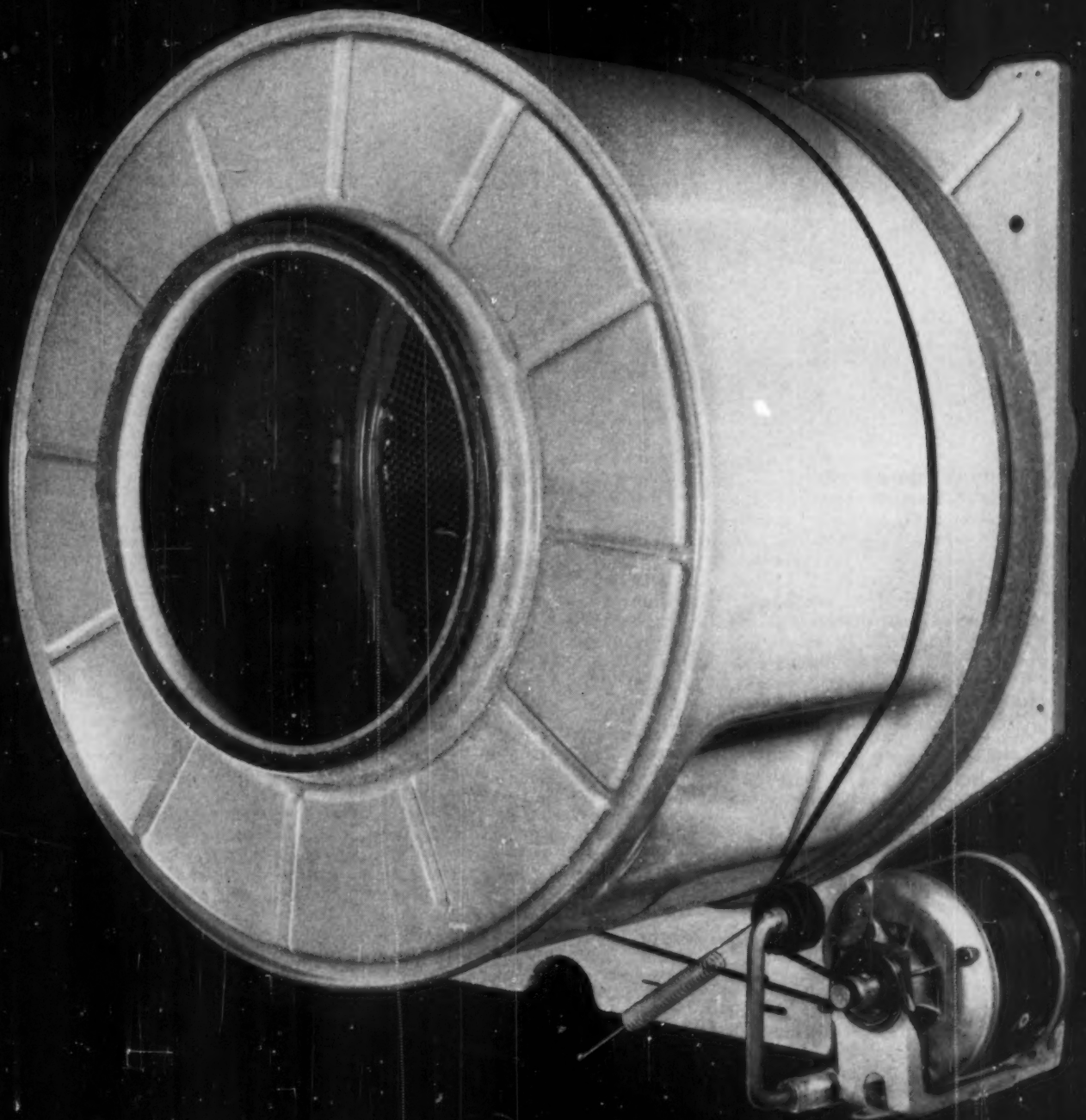
Drive Engineering Service Perhaps your product's performance can be improved—costs lowered—with a Dayton Poly-V Drive. A call to your nearby Dayton engineer will bring you the assistance and advice of an experienced drive specialist. Or write directly to: Dayco Corporation, Dayton Industrial Products Co., Div., Melrose Park, Illinois.

Dayco CORPORATION

Dayton Industrial Products Co. Div. Melrose Park, Illinois

CIRCLE 66 ON READER SERVICE CARD

in 36:1 reduction...



Full contact design

enables Dayton Poly-V belt
to track perfectly over drum surface
—without grooves or guides

ment with clutching or braking. Clutch torque at 28 v dc excitation: engaged, 6 oz-in. min; disengaged, 0.05 oz-in. max. Brake torque is 2 oz-in. min. Reportedly show no torque variation with fluctuating temp up to 257 F. Other specifications: weight, 0.97 oz; min engagement voltage, 6 v dc; power consumption, 1.16 w at 28 v; response time at 28 v dc, 2.8 millisec; inductance, 0.33 Henries; polar moment of inertia, 1.13 gm-cm² (engaged), 0.78 gm-cm² (disengaged); backlash, 0 min. of arc engaged; and temp rise at 77 F, 54 F. From stock. **Clifton Precision Products Co Inc, 5050 State Rd, Drexel Hill, Penna.**

Circle 313 on Reader Service Card

Latch-type footswitch . . .

for maintained contact operation of machines and process cycles, has auxiliary pedal on side to act as a release for main pedal. When operator depresses main pedal, release pedal catches and holds it. Depressing auxiliary pedal releases main pedal. Available with either 1 N.O. and 1 N.C. contact or 2 N.O. and 2 N.C. contacts. Has heavy-duty, water-and-oil-tight gasketed NEMA IV enclosure. **General Electric Co, Schenectady 5, NY.**

Circle 314 on Reader Service Card

Pilot valves . . .

are direct solenoid-operated with spring returned plungers. All sizes have ¼-in. pipe taps and are suitable for pressures up to 3000 psi. Solenoid is totally enclosed and sealed against moisture and contaminated atmospheres. Stem in solenoid cover permits manual valve operation for setup and troubleshooting. Bodies are alloy iron; plungers, alloy steel. Over-all dimensions: 11 x 4 x 4 in.; net weight, 20 lb. **Oilgear Co, 1570V W Pierce St, Milwaukee 4.**

Circle 315 on Reader Service Card

Miniature pressure transducer

is potentiometer-type, "center pillar" constructed unit available in ranges from 1 to 200 psi, either gage or absolute. Platinum alloy winding element with optional resistance from 5000 to 15,000 ohm provides typical resolution of 0.25-0.33%. Linear or nonlinear outputs are available with conformity of 1% or better. Repeatability, hysteresis and friction are typically under 0.5%. To handle corrosive media, an all-welded stainless steel case with Inconel-X capsule can be furnished. Unit measures 1 in. dia x 1¼ in. long. **Princeton Machine & Development Co, PO Box 187, Princeton Junction, NJ.**

Circle 316 on Reader Service Card

Lug press-on wheel . . .

is said to have twice as many lugs as any other press-on, providing better grip and increased traction. Made of polyurethane elastomer, which resists abrasion and prevents lugs from "chunking" out in a short time. Wheel also is highly resistant to oils and chemicals. Available as cushion- or solid-type tires in standard press-on sizes. **Disogrin Industries, Div of Pellon Corp, 510 S Fulton Ave, Mt Vernon, NY.**

Circle 317 on Reader Service Card

General-purpose relay . . .

has two built-in gasket seals. One lies between base and transparent butyrate cover; other is between side mount washer and cover. Has electrically insulated nut and thru-bolt running through locator key which is said to minimize locator key breakage and reinsertion problems. Available to 3PDT in both 5- and 10-amp contact ratings. Furnished in production quantities from 6 to 110 v dc, 6 to 230 v ac and 2.5 to 10 k plate circuit relays. **Milwaukee Relays Inc, PO Box 3175, Milwaukee 18.**

Circle 318 on Reader Service Card

Block valves . . .

for high vacuum systems, are machined from solid brass square stock and are available with in-line or angle configurations for soldered or screwed connections in sizes from ¼ to 1½ in. All models under 1 in. use same bellows assembly minimizing number of spare assemblies needed to maintain a vacuum system. Assembly, sealed to valve body by an O-ring, is removed without changing alignment of valve body by loosening four screws. Standard O-rings and disk gaskets are Neoprene, with other materials supplied on request. Valves reportedly have high conductance. In many models, special long-stroke brass bellows allow disk to lift completely clear of inlet opening. Tests have shown an average of over 10,000 complete excursions (opening and closing) before bellows failure. Bellows stem seal is said to assure leakproof operation. **NRC Equipment Corp, 160 Charlemont St, Newton 61, Mass.**

Circle 319 on Reader Service Card

25-amp silicon-controlled rectifiers . . .

eliminate need for using low-current units in parallel to handle high-current applications. Rated for an average rectified forward current of 25 amp at 212 F, carrying a max dc current of 35 amp at 203 F. Rated breakover voltages, both forward and reverse, are 50, 100, 200, 300 and 400 v, respectively, for five models. All are produced by an all-diffusion technique and are from stock. **Texas Instruments Inc, PO Box 5012, Dallas 22, Tex.**

Circle 320 on Reader Service Card

Sleeve bearing . . .

is self-lubricating, self-aligning unit in flanged and pillow block types. Operates in temps up to 1000 F; in corrosive and contaminating conditions; in inaccessible locations where lubrication and maintenance are problems; where noise control is needed; at slow speed and under water. Cartridge is held in position in housing by a set screw, which, when backed off, allows cartridge to be rotated 180°. This is done without removing bearing from shaft and reportedly doubles service life. Available in shaft dia sizes from ½ to 3 15/16 in. **Link-Belt Co, Dept PR, Prudential Plaza, Chicago 1.**

Circle 321 on Reader Service Card

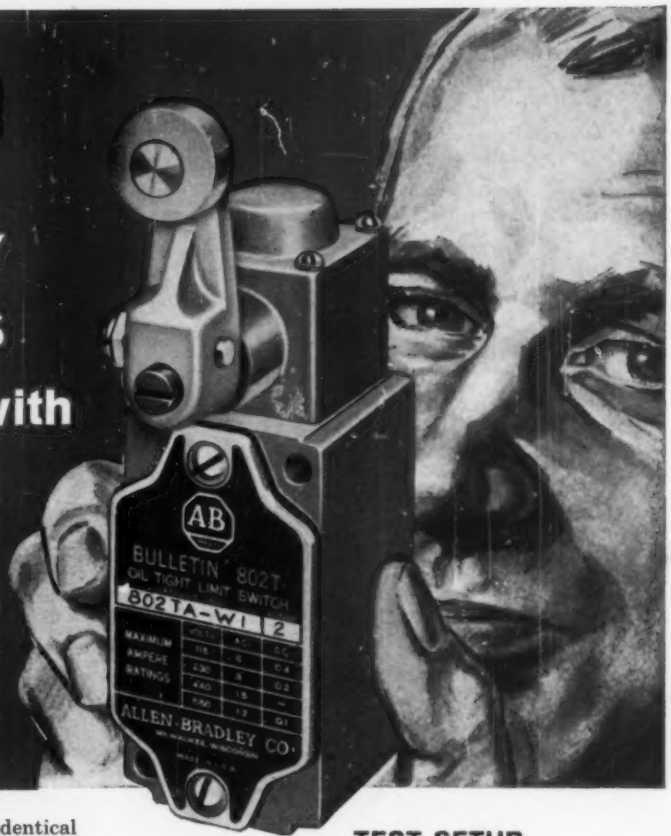
Absolute-pressure transducer

has static error band specification of ±1.2%, indicating high performance. Low friction design concepts are used through-

continued on page 73

Only ALLEN-BRADLEY LIMIT SWITCHES FINISHED TEST with *NO FAILURES!*

...and remained good for many more millions of trouble free operations

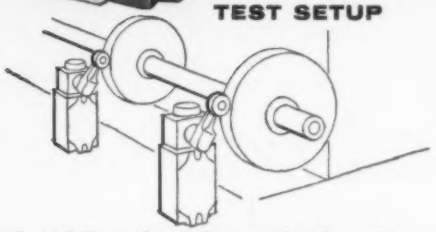


Recently, a large user of limit switches selected two identical units from each of five leading manufacturers and subjected them to the same accelerated life test. When the test was stopped after many, many millions of operations, only Allen-Bradley Bulletin 802T oiltight limit switches were left *with no failures!* Also, a careful inspection of these two Bulletin 802T limit switches suggested that they were still good for *many more millions* of operations.

The Allen-Bradley "built-in" quality is the reason for such unmatched performance. With switch bodies and operating heads positively sealed against oil and dirt, A-B Bulletin 802T limit switches are free from contact fouling and sluggish operation. The precision switch mechanism has a positive snap action—it is impossible for vibration to cause contact chatter. The double break, silver contacts never need servicing.

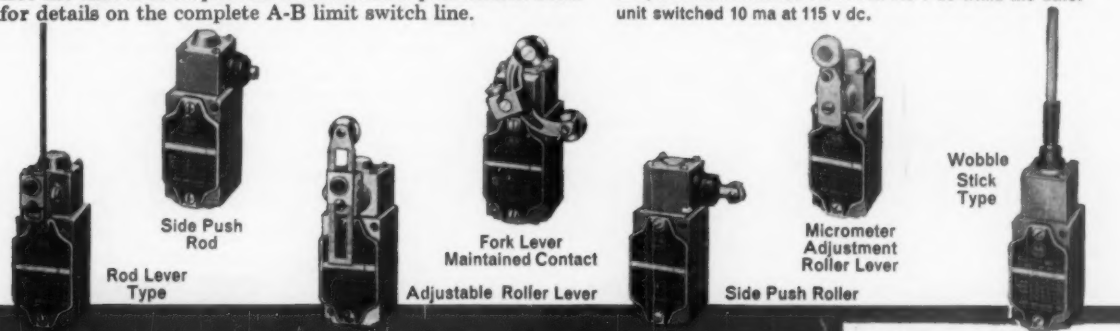
Insist on Allen-Bradley Bulletin 802T oiltight limit switches—they will *always* provide you with the long, trouble free life that is so important to continuous production. Send for details on the complete A-B limit switch line.

TEST SETUP



Purchased through regular supply channels . . .

and tested under identical conditions, insuring an impartial evaluation of performance. Of the ten limit switches tested (two each of five different makes), only three were operating when the test was stopped. Two were A-B Bulletin 802T switches and one of another make, of which the second unit had failed early in the test. On this accelerated life test, one unit switched 1.0 ma at 115 v dc while the other unit switched 10 ma at 115 v dc.



ALLEN-BRADLEY

Member of NEMA

QUALITY MOTOR CONTROL

Allen-Bradley Co., 1329 S. First St., Milwaukee 4, Wis. • In Canada: Allen-Bradley Canada Ltd., Galt, Ontario

WHO MAKES GEARMOTORS THIS SMALL?

Globe Industries makes d.c. (and a.c.) gearmotors this small to make your design more compact, reliable and salable. If you need an exact speed-torque combination in a precisely engineered package, look at these 4:

TYPE VS—Motor is 7/16" flat, develops .0025 hp @ 8,000 to 17,000 rpm, and can use our standard modular spur gearing in 62 ratios. Continuous duty torques to 35 oz. in. available. Gear box can be side mounted (as shown) or end mounted with a frontal area of only 0.4 square inch.

TYPE SS—a 7/8" diameter d.c. motor that develops .004 hp @ 8,000 to 17,000 rpm. Compatible gearing system has 21 planetary ratios or 28 spur gear ratios. Continuous duty torques available to 300 oz. in. Governors, brakes and filters designed to meet MIL specs also.

TYPE MM & LL—Most widely used 1 1/4" diameter precision miniature motors and gearmotors in the world. Choose from 101 standard planetary ratios; torques to 1000 oz. in. Because these and other Globe motors have many standard armature windings, it's easy to get the exact speed-torque combination you need. Motors to .015 hp @ 6,000 to 15,000 rpm.

TYPE BD & BL—1 1/2" diameter d.c. motors with planetary gearing in 22 ratios. Unit illustrated provides up to 100 in. lb. continuous duty. With a 3" final stage, continuous duty torques to 500 in. lb. (1000 in. lb. intermittent) are available. These can replace units 5 times their size and weight. Motors to .033 hp @ 4,000 to 10,000 rpm.

Delivery is prompt; cost is reasonable. For details about d.c. and a.c. gearmotors request bulletin GGM from Globe Industries, Inc., 1784 Stanley Avenue, Dayton 4, Ohio.

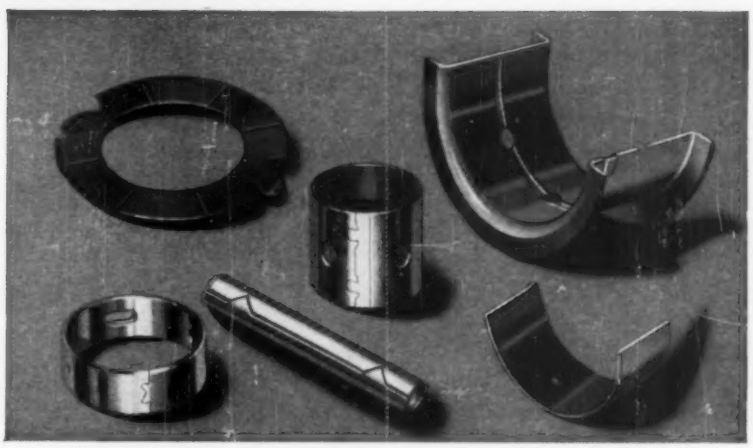
GLOBE INDUSTRIES, INC.

PRECISION MINIATURE MOTORS, GEARMOTORS, TIMERS, ACTUATORS, CLUTCHES, BLOWERS, MOTORIZED DEVICES

GLOBE

75-MILLIONTHS OF AN INCH BARRIER HALTS METAL MIGRATION

JUST BENEATH THE FRESH OVERPLATE OF THESE F-M ENGINE BEARINGS (LEFT) LIES A TENUOUS DIFFUSION BARRIER. Though this film of metal is only 75-millionths of an inch thin, it stops tin in the overplate from migrating into the lining metal beneath. Its presence is important to bearing overplate performance, particularly during the critical period of engine break-in. Maintaining uniform thinness as well as uniform composition of the plated barrier is most important . . . and most difficult to achieve on a production scale. Federal-Mogul research has developed a unique, extraordinarily precise method for controlling both the thinness and the metallic composition of this barrier, within narrow limits. And the performance of F-M engine sleeve bearings attests to the success of the method!



RESEARCH INTO ELECTROPLATING problems is a continuing project in the F-M laboratories. Unusual precision equipment and facilities are employed, many of which have been specially designed and engineered by F-M to solve problems of sliding-bearing application. As a result, Federal-Mogul engineered sleeve bearings, precision thrust washers, formed bushings, and low-cost spacers provide the finest possible performance characteristics for any application.

Have you a problem with bearings, bushings or washers? Are you considering the development or redesign of an item of the type shown above? We'll be glad to show you how the job can be done most effectively and economically. For information, write Federal-Mogul Division, Federal-Mogul-Bower Bearings, Inc., 11043 Shoemaker, Detroit 13, Michigan.

FEDERAL-MOGUL

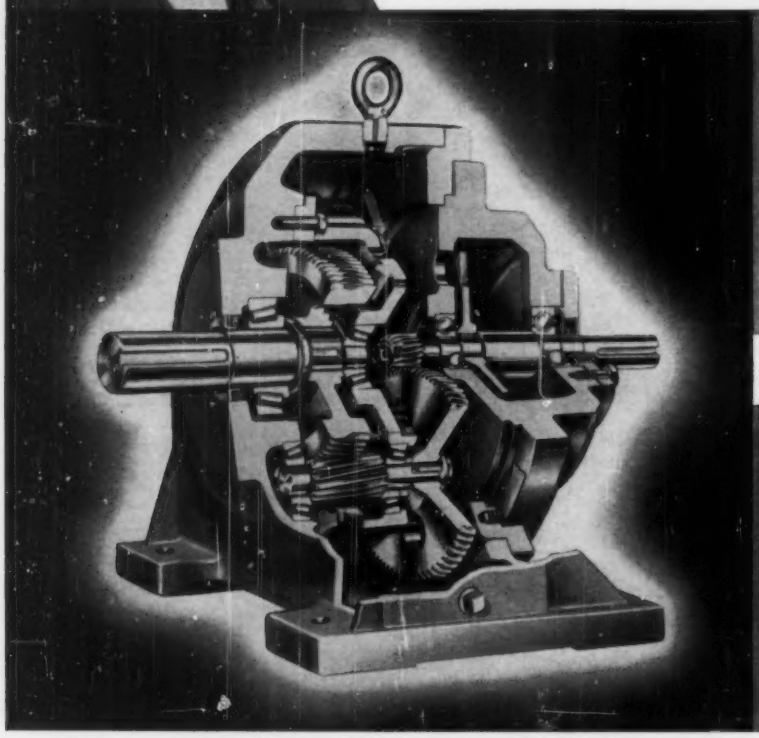
sleeve bearings
bushings-spacers
thrust washers

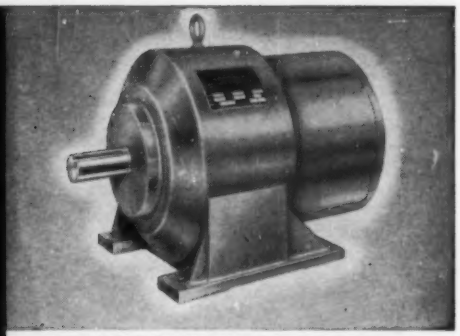
DIVISION OF
FEDERAL-MOGUL-BOWER
BEARINGS, INC.

CIRCLE 71 ON READER SERVICE CARD 71

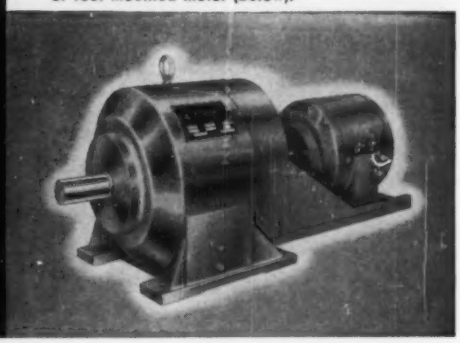
"Buying at Philadelphia Gear, I get the benefit of this simple formula..."

IMPROVED GEARS = [LONGER LIFE / MORE POWER]





Available as "IN-LINE" Reducer (left), or as a GearMotoR with flange mounted motor (above) or foot mounted motor (below).



The gearing in these drives is case hardened and precision ground, an advanced development that out-dates conventional standards and ratings. You get commercial drives with gearing of master gear quality at a cost no greater than conventional drives now in use. They are available in standard sizes to 200 H.P.

LONGER LIFE
Extreme accuracy of tooth profiles, profile spacing and surface furnish eliminates "running-in" wear.

MORE POWER
Harder materials, plus reduced load factors means the reducer can transmit more power, operate at higher speeds.

SPACE AND WEIGHT SAVINGS
Reduced load factors also mean less space and weight without sacrificing performance characteristics.

REDUCED VIBRATION
Reduced tooth to tooth errors, accumulated pitch errors and total composite errors give smoother contact.

REDUCED SOUND LEVELS
For applications where low sound levels are important, gear noise is no longer a controlling factor.

FOR MORE INFORMATION
Send for our new Catalogs R-60 (IN-LINE Reducers) and GM-60 (GearMotoRs).

philadelphia gear drives

PHILADELPHIA GEAR CORPORATION
King of Prussia (Suburban Philadelphia), Pennsylvania

out, and multiplying linkages are replaced by direct acting electrical pickoff. Potentiometer wiper is driven directly by helical Bourdon tube, producing high-level ac or dc signal proportional to input pressure. Range is 0-4000 to 0-10,000 psi; resistances, 1 k to 10 k ohm ±5%; resolution, down to 0.2%; and vibration, 16-35 g, 25-2000 cps. Measures 1 in. dia x 1.48 in., exclusive of connector and pressure fitting. Weighs approx 4 oz. **Bourns Inc, 6135 Magnolia Ave, Riverside, Calif.**

Circle 322 on Reader Service Card

Spring-loaded filler caps . . .

are made of die-cast aluminum alloy and are available from stock with 2-, 1¼- and ⅝-in. free openings. Cap, which snaps open or closed, cannot be dropped or lost, requires no chain. O-ring provides tight sealing, while breather vent can be included. **Technical Development Co, 303 S Chester Pike, Glenolden, Penna.**

Circle 323 on Reader Service Card

Highly sensitive relays . . .

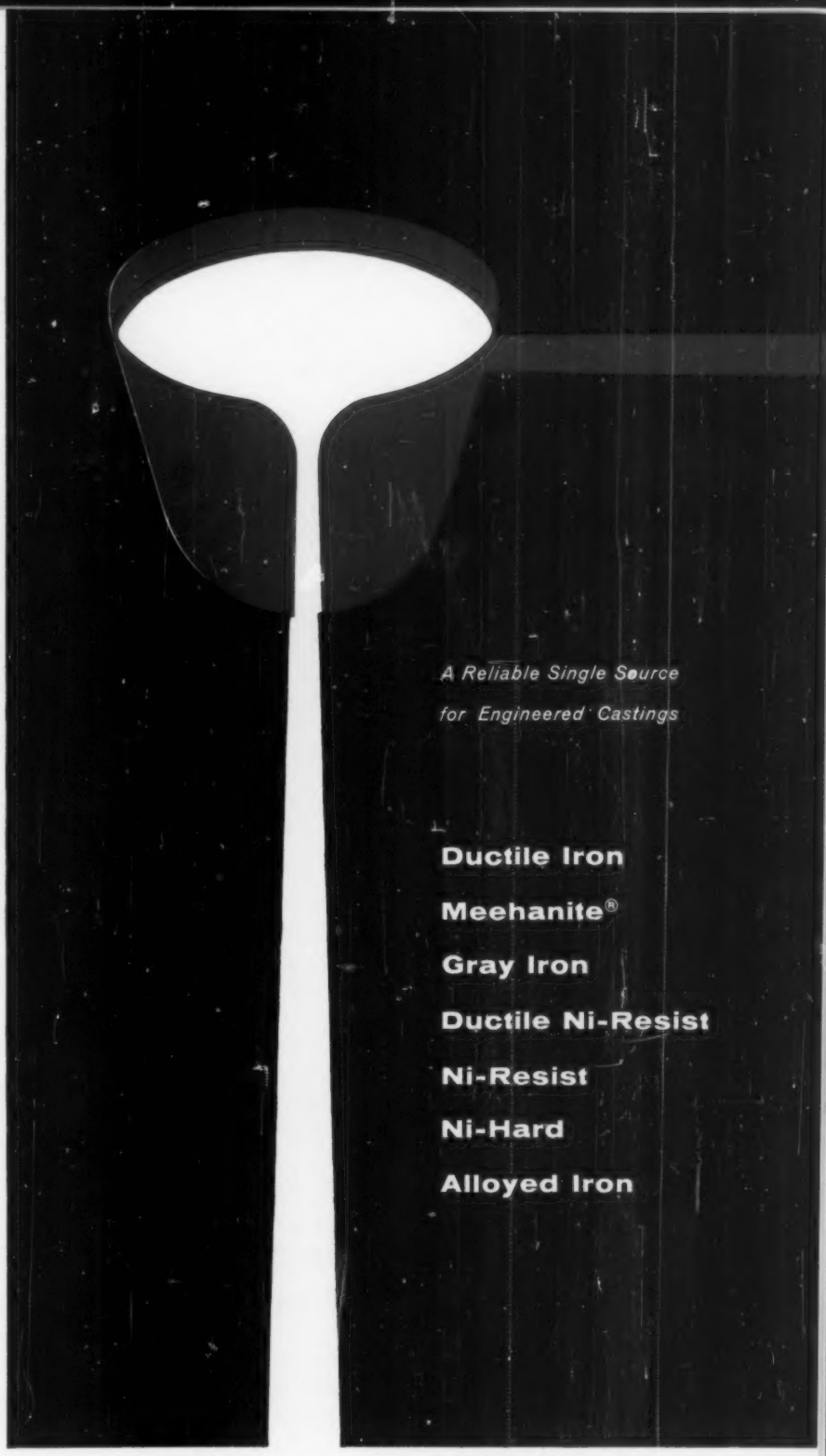
can be either plugged into a printed circuit board or screwed to frames to allow for soldered leads. A 50-milliw unit has coil impedances as high as 5000 ohm; pull-in at 3.2 milliamp; and drop-out at above 0.5 milliamp. Each type is available with choice of three contacts: SPDT, SP normally open and SP normally closed. Contact rating is 1 amp, 28 v dc or 120 v ac, noninductive. Over-all dimensions: 1.3 x 1.2 x 1.2 in.; weight, 1.1 oz. **Lionel Corp, Electronics Div, Hoffman Pl, Hillside, NJ.**

Circle 324 on Reader Service Card

Ceramic-metal composites . . .

using a variety of substrate metals, are available on a limited production basis. Composite consists of ceramic structure characterized by a large number of very small crystals that are physically and chemically bonded to a structural substrate metal. Said to have high resistance to corrosive attack at between 500 and 1500 F, which few metals withstand even for limited time, and reportedly top corrosion-resistant ceramic materials in me-

continued on page 76



HAMILTON FOUNDRY INC.

1551 LINCOLN AVENUE • HAMILTON, OHIO • TWinbrook 5-7491

CIRCLE 73 ON READER SERVICE CARD

1 HIGH-SPEED OPERATION
Balanced release levers permit high-speed drives. Lever "throwout" is eliminated for longer bearing life. Patented anti-friction rollers give instant release with minimum pedal pressure.

2 ACCURATE FIT
Close-tolerance drive between cover and pressure plate assures smooth starts. Highly accurate bolt circle fits flat flywheels—accurate outside pilot diameter fits counterbored flywheels.

3 VIBRATION DAMPENER
Coil-spring vibration dampener absorbs vibrations between engine and transmission. Noise, rattle and thrash in the gear train are eliminated for smooth, quiet clutch operation.

ROCKFORD SPRING-LOADED CLUTCH

International model C-130 Dump Truck equipped with Rockford Spring-Loaded Clutch

4 HIGH-TORQUE DESIGN
Powerful engagement springs, properly spaced over the facing area, assure maximum driving contact. Compact, low-inertia design prevents gear clashing and delayed shifting.

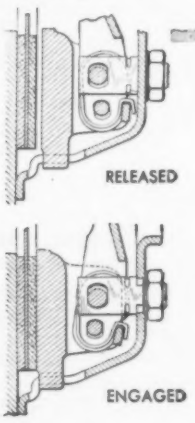
5 SMOOTH ENGAGEMENTS
Dynamic and static balancing assures you of smooth, enduring clutch performance. Both driving and driven members are balanced to eliminate vibration.

6 HIGH-TEST FACINGS
Using only the highest quality facings, Rockford Clutches give extra-long clutch life, provide cushioned starts, reduce scoring and greatly cut costs of downtime replacement and labor.

7 PERFECT ALIGNMENT
Close-tolerance splined hub assures perfect disc alignment. Through-hardened hub gives long life. Precision manufacturing and rigid quality control eliminate chances for misalignment.

7 Good Reasons Why Idea-Men Count on Rockford Reliability

Above are seven reasons why more and more design men specify Rockford Spring-Loaded Clutches. Equally important, ROCKFORD RELIABILITY is due to 63 years of creative engineering, precision manufacturing and rigid quality control. Rockford offers complete design engineering service at no cost or obligation. You're backed by a worldwide service network. Write today for complete details on ROCKFORD RELIABILITY.



ROCKFORD CLUTCH

209 CATHERINE STREET, ROCKFORD, ILLINOIS

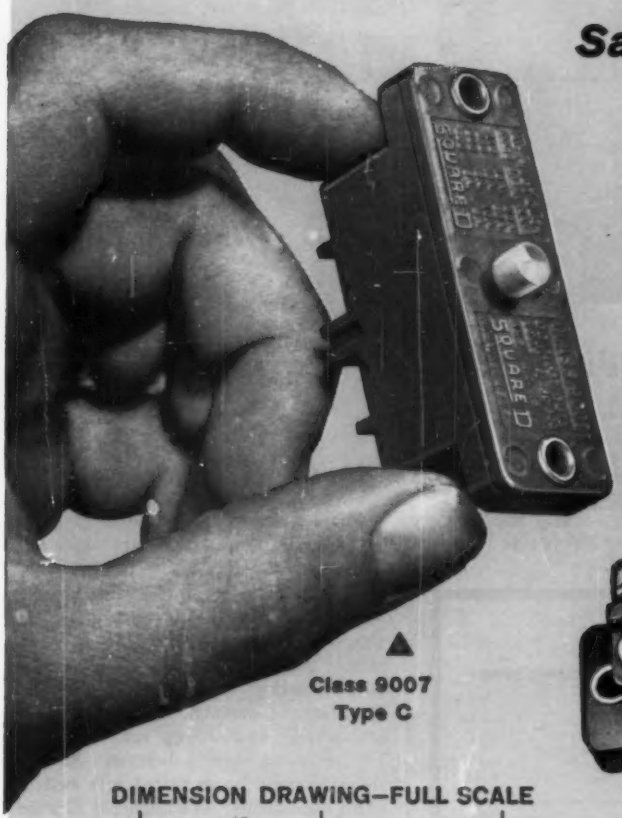
Export Sales Borg-Warner International • 36 So. Wabash, Chicago, Ill.

ROCKFORD BW CLUTCH

DIVISION OF BORG-WARNER

Now!..

SQUARE D PRECISION *SNAP* SWITCH AVAILABLE WITH 2 POLES!



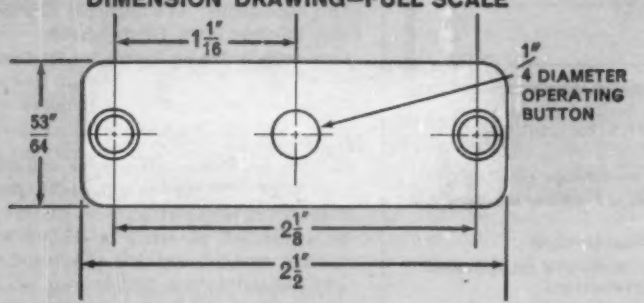
▲ Class 9007 Type C

Same size and mounting as single-pole switch

Here's a precision snap switch which combines 2-pole versatility with high electrical ratings—and takes no more space than a single-pole switch!

The new switch is available either single-throw (2 normally open or 2 normally closed) or double-throw, and like the single-pole switch, it features: double-break contacts—large screw-type terminals—strong melamine case—simplified mounting...a design which assures reliability, precise repeat accuracy and long mechanical life.

DIMENSION DRAWING—FULL SCALE



Write for details. Square D Company, Dept. SA
4041 North Richards Street, Milwaukee 12, Wisconsin

SQUARE D COMPANY

wherever electricity is distributed and controlled

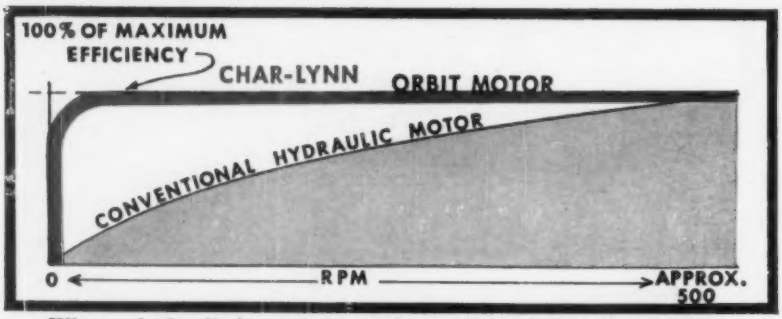
You've never seen a motor like this!

PAT. NO. 2,821,171

A High Torque, Low Speed Hydraulic Motor

It's Here—A NEW concept in fluid power mechanics has brought about the development of a totally new fluid motor—A *High Torque—Low Speed* motor.

These motors open up complete new areas for design, never before possible. They offer a practical and economical hydraulic solution to the age-old problem of providing High Torque at Low Speeds for constant and variable speed drives—hydrostatic transmissions and remote controls *without* bulky, costly mechanical drives and gear reducers.



Whereas hydraulic losses make some conventional designs prohibitive at the lower speeds, Char-Lynn ORBIT MOTORS maintain high efficiency over the complete operational range.

- Speeds from 0—800 RPM
- Torques to 3300 inch lbs.
- Starting torque substantially equal to running torque
- Fully reversible — instantaneous starting—stopping
- Only 3 moving parts
- 4 types of mountings available
- 3 port sizes—7 power element selections
- Compact—lightweight
- Eliminates costly and complicated power transmissions
- High volumetric and overall efficiency

Write for complete 8 page brochure on ORBIT MOTORS

HYDRAULIC HORSEPOWER PRODUCTS

chanical strength, thermal shock resistance, abrasion and erosion resistance, heat conductance and hi-temp stability. Specific ceramic formulations have been developed for carbon steel and for more than a dozen other metal substrates. At temps from 450 to 700 F, carbon steel is recommended as the metal substrate. From 750 to 1500 F, stainless steels, Inconel or "refractory" metals are required. Tests samples are available in four standard forms: cup, well, spool and dumbbell. **Pfaudler Co, Div. of Pfaudler Permutit Inc, 1129 West Ave, Rochester, NY.**

Circle 325 on Reader Service Card

Switchboard instruments . . .

said to be low-priced, have taut-band suspension systems, using no pivots or bearings and eliminating all wear. Includes ac and dc ammeters and voltmeters, watt meters, varmeters and frequency meters. Basic flange size is 4½ in. sq; scale length, 4 in.; and scale arc, 100°. Dc instruments, using core-magnet construction, are shielded against external magnetic fields. These can be mounted within 2 in. of a bus carrying 10,000 amp with less than ½% effect on their indication. Ratings are those normally associated with switchboard instruments. **Westinghouse Electric Corp, PO Box 2099, Pittsburgh 30.**

Circle 326 on Reader Service Card

Vane axial blower . . .

is suitable for both high altitude and sea level operation. Has output of 95 cfm air at 2.5 in. water at sea level and 140 cfm air at 2.1 in. water at 25,000 ft. Standard model is for 200 v ac, 400-c, 3-phase operation, but models using other power, including dc and universal ac/dc, can be designed. Unit is 4.15 in. dia x 2.5 in. long, weighs 2 lb, and has turning vanes to support the motor inside its black anodized cast aluminum housing. Rated for 1000-hr life at 159.8 F at sea level. **Globe Industries Inc, 1784 Stanley Ave, Dayton 4, Ohio.**

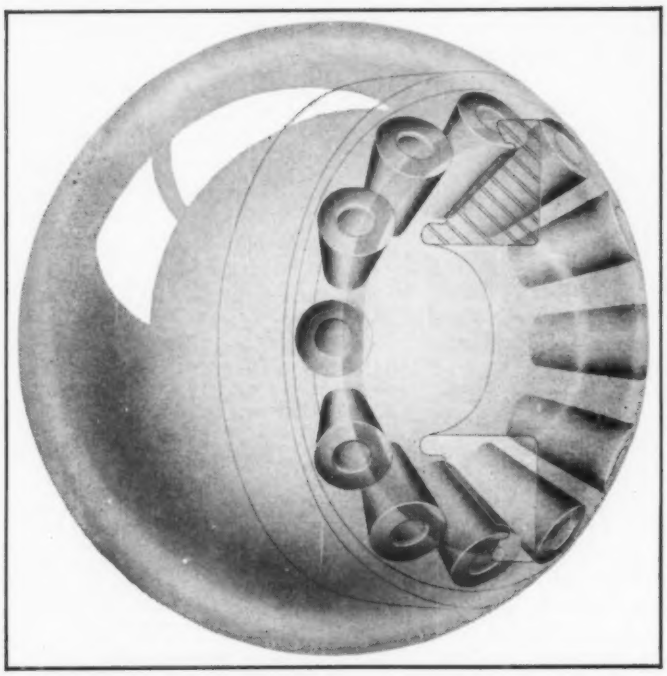
Circle 327 on Reader Service Card

continued on page 78

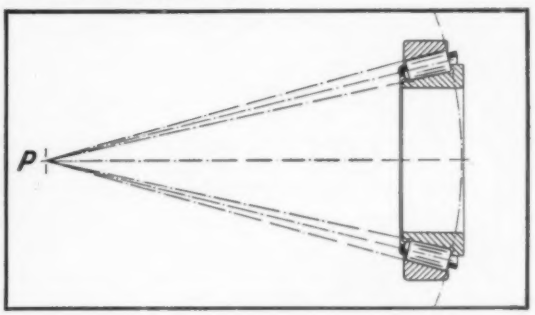
BEARING BRIEFINGS

One in a series of technical reports by Bower

SPHERICITY — ESSENTIAL TO MAXIMUM BEARING PERFORMANCE



When you require bearings, we suggest you consider the advantages of Bower bearings. Where product design calls for tapered or cylindrical roller bearings or journal roller assemblies, Bower can provide them in a full range of types and sizes. Bower engineers are always available, should you desire assistance or advice on bearing applications.



True rolling of tapered bearing elements depends upon maintaining a true spherical radius during manufacture.

For a tapered roller bearing to achieve maximum performance, i.e., maximum life and capacity under load, it must have true sphericity — a condition of bearing geometry which permits true rolling of the tapered rollers in the raceway.

True rolling in tapered bearing elements is the result of maintaining a critical geometric relationship between the raceways and the contact surfaces of each roller. True rolling is essential to maximum performance. Without it, premature bearing failure is certain.

As engineers know, a tapered roller will describe a true circle when rolled on a plane surface. *It will always roll in this one path precisely, without sliding or skewing.* But to put true rolling to work in a bearing which can carry both heavy thrust and radial loads, it is essential that the rollers *and* the raceway have a true spherical radius, or sphericity. The drawing illustrates this condition.

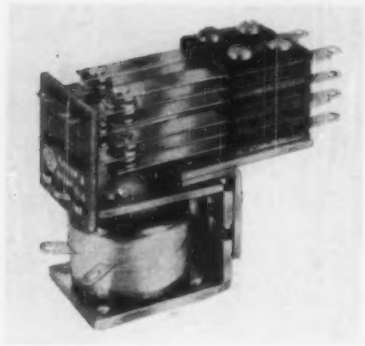
If each roller in the bearing were to be extended in length, while retaining its taper, it would form a cone, terminating at point "P". All cones generated from all rollers would meet at point "P", which is also the center of the hypothetical sphere shown. The surface of the sphere would *touch all points on each roller's head!*

In effect, then, each roller's taper determines the radius of a hypothetical sphere whose surface, in turn, determines the correct contour for each roller head. Only when these conditions are satisfied in design, and when they are rigidly held during manufacture, will true rolling take place. In the manufacture of each Bower tapered roller bearing, sphericity is held within extremely narrow limits by means of special Bower-designed precision grinders. The consistent accuracy possible with these machines is one major reason why Bower roller bearings provide maximum performance under all speeds and loads up to the bearing's maximum rating.

BOWER ROLLER BEARINGS

BOWER ROLLER BEARING DIVISION — FEDERAL-MOGUL-BOWER BEARINGS, INC., DETROIT 14, MICHIGAN

CIRCLE 77 ON READER SERVICE CARD



15-amp relay . . .
for motor loads up to ½ hp, has phosphor bronze contact arms approx ¼ in. longer than on similar relays. These are said to provide more contact overtravel, resulting in top wiping or self-cleaning action. Made to last for min of 10 million mechanical operations. Contact arrangements range from SPST to 4PDT. Standard models with ¼-in. dia silver contacts are rated 15 amp at 115 v ac or 28 v dc. Silver cadmium oxide contacts are recommended for motor loads. Coils for ac version operate on from 6 to 230 v ac, 50/60 c. DC coils are available to operate on 6 to 110 v. The 4PDT unit measures 2 13/32 x 3 9/32 x 1 in. **Potter & Brumfield, Princeton, Ind.**

Circle 328 on Reader Service Card

Mobile vertical file . . .
can be adjusted to accommodate sheets up to 36 x 48 in. Holds 12 binders and files up to 1200 sheets. Has tubular steel frame equipped with ballbearing casters, weighs less than 18 lb, and occupies only 3 sq ft of floor space. Rack is priced at $19.95; binders from $4.40 each. **Plan Hold Corp, 5204 Chakemco St, South Gate, Calif.**

Circle 329 on Reader Service Card

DESIGN LITERATURE

The Measure of Man

HENRY DREYFUSS. Whitney Library of Design, 18 E 50th St, New York 22. 9¾ x 12⅝. $4.95.

This folder of material deals with those human factors involving anthropometric dimensions important to product design that have appeared in a number of periodicals (including PRODUCT ENGINEERING) over the years, since their development began during World War II. Now they have been brought up-to-date and reflect much of the newest data developed by a number of governmental and other organizations, including the industrial design staff employed by the author himself.

Included in the hard-cover folder is a 16-pp booklet containing a foreward; nomenclature (for the anthropometric diagrams and charts); a checklist of product elements wherein human factors are generally involved; a bibliography; diagrams of standing and sitting adults and children together with data on visual, motion, control and display data; life-size diagrams of adult male and female figures.

As the reader is repeatedly warned in the foreward, this material is suitable only as a guide to the application of human-factors phenomena to product design—none of the information can be considered as a "handbook" or "manual" ready for instant-application to controls, data display or dynamic seating. Instead, it is to be used as a highly useful adjunct to the designer's own imagination in fitting his work more exactly to its ultimate consumers.

And as Mr Dreyfuss points out, human-factors data is constantly changing: new information is being developed all the time and people themselves change—as well as the tasks they are called upon to perform. He suggests that following the literature regularly is the ultimate answer, and points to the bibliography he has included as a good place to begin (see also *PE—Sep 12 '60, pp 71-74*).—JK

Nondestructive Testing

WARREN J McGONNAGLE. McGraw-Hill Book Co Inc, 330 W 42nd St, NY 36. 6 x 9¼, 455 pp. $15.

The physical principles, techniques, advantages, and limitations of the various methods of nondestructive testing are covered in detail. Based on applied physics, the treatment in the book stresses non-destructive testing as a science, and outlines the what, why, how, when, and where of this rapidly developing technology. This type of testing is concerned not only with the detection and location of flaws in material, but also with the measurement of physical properties or nonuniformities in the physical properties of specific materials.

Among the major testing procedures treated here are visual testing, pressure and leak testing, liquid-penetrant inspection, thermal methods, X-ray and gamma radiography, ultrasonics, dynamic testing, magnetic and electric techniques, and eddy current methods.

Other topics include nondestructive test work in the field of atomic energy, thickness measurements, and specialized techniques as spot tests, sulfur printing, spectrochemical analysis, spark testing, activation analysis and residual stress.

Other Books of Interest

The Control of Multivariable Systems

M D Mesarovic. John Wiley & Sons Inc, 440 Park Ave South, NY 16. 6 x 9¼, 112 pp. $3.50.

Suggests that future theory about control systems should rest on a multivariable rather than single-variable foundation. Recommends specific control structural patterns.

Heat-resistant Elastomeric-Material Combinations and Forms

PB 161813. Office of Technical Services, US Dept of Commerce, Washington 25, DC. 8 x 10½, 39 pp. $1.25.

Capsule Summary Completed AGEP Projects in the Area of Electronic Parts and Materials 1 July 1954–31 August 1960

AGEP Secretariat, Moore School Building, 200 S 33 St, Philadelphia 4. 8¼ x 11, approx 75 pp.

Solar Cell and Photocell Handbook

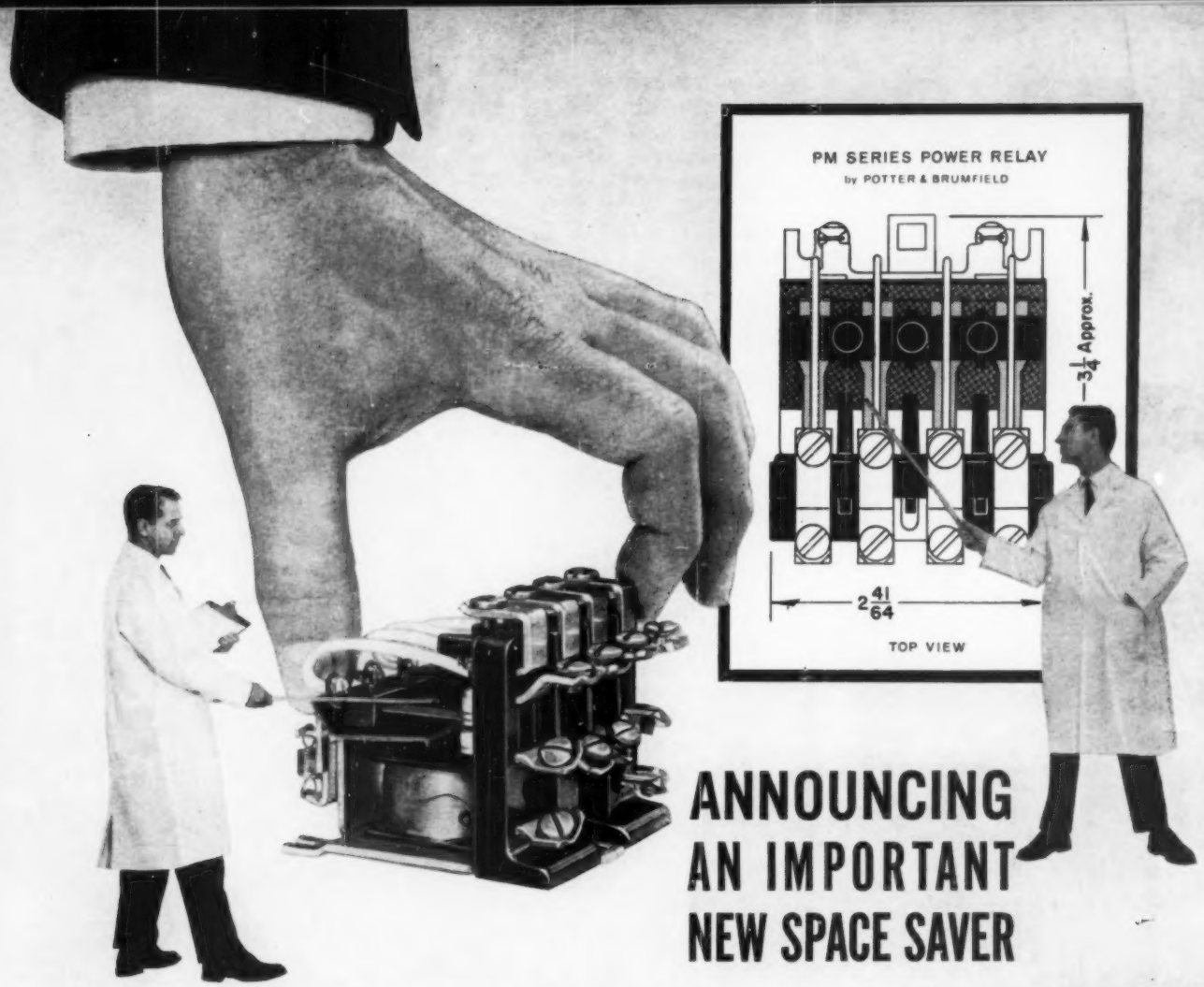
J Sasuga. International Rectifier Corp, El Segundo, Calif. 6 x 9, 111 pp. $2.

Empirical Equation for Turbulent Forced-convection Heat Transfer for Prandtl Numbers from 0.001 to 1000

U H von Glahn. Office of Technical Services, US Dept of Commerce, Washington 25, DC. 8 x 10¼, 16 pp. 50¢.

continued on page 80

CIRCLE 79 ON READER SERVICE CARD→



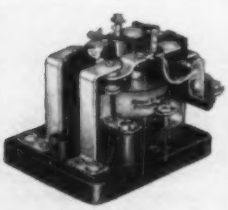
ANNOUNCING AN IMPORTANT NEW SPACE SAVER

P&B compact 4PDT power relay switches one H.P. per moveable arm

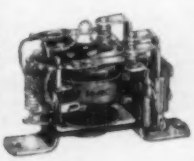
Save panel space! This new 4-pole relay is only 1/16" wider than our PR Series, America's most popular 2-pole power relay! Yet, it is engineered for reliable heavy-duty switching . . . and you can confidently expect 10 million mechanical operations.

PM Series relays are rated at 16 amperes (or 1 H.P.) at 115 volts, 50/60 cycles resistive . . . and special relays can be supplied for loads up to 25 amperes, at 220 volts, 50/60 cycles resistive. Heavy screw terminals are arranged for fast, easy hook up. An adapter plate is available for mounting PM relays in the same location used for 2-pole relays.

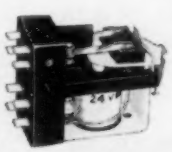
For full information, write today or call your nearest P&B representative.



PR Series



MR Series



AB Series

A whole family of power relays for a wide range of applications carry the P&B symbol of quality. Call P&B first for all your power relay requirements.

PM ENGINEERING DATA

GENERAL:

Description: Heavy-duty AC power relay.
Insulating Material: Molded phenolic.
Insulation Resistance: 100 megohms minimum.
Mechanical Life: 10 million operations minimum.
Contact Life: 100,000 operations minimum at rated load.
Breakdown Voltage: 2,000 volts rms minimum between all elements and ground.
Ambient Temperature: −55°C to +55°C.
Weight: Approximately 14 ozs.
Pull-In: 78% of nominal voltage.
Terminals: Heavy-duty screw type with No. 8-32 BH screw.

CONTACTS:

Arrangements: 4PDT or 4PST—normally open.
Material: ¼" dia. silver-cadmium-oxide.
Rating: 16 amps @ 115 volts, 50/60 cps resistive.
8 amps @ 220 volts, 50/60 cps resistive.
1 H.P. per moveable, 115 or 220 volts AC single phase.
25 amps @ 220 volts, 50/60 cps resistive available on special order.

COILS:

Voltage: 6 to 230 volts AC 50/60 cycles.
Power: 14 volt-amps average at nominal voltage.
Duty: Continuous.

P&B STANDARD RELAYS ARE AVAILABLE AT YOUR LOCAL ELECTRONICS PARTS DISTRIBUTORS

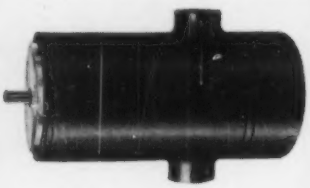
AMF **POTTER & BRUMFIELD**

DIVISION OF AMERICAN MACHINE & FOUNDRY COMPANY • PRINCETON, INDIANA

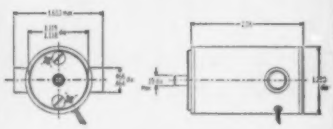
IN CANADA: POTTER & BRUMFIELD, DIVISION OF AMF CANADA LIMITED, GUELPH, ONTARIO

DC

Another precision motor from Motordyne capable of meeting the most stringent specifications. Hundreds of planetary gear speed reducers are offered as well as brakes, governors, clutches and thermal overload switches.



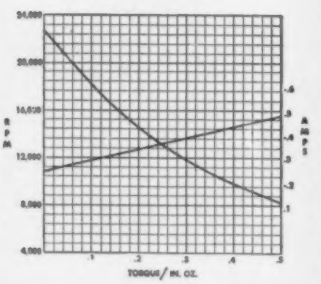
SERIES 1200, REVERSIBLE MOTOR



Power Supply	24-28 volts
Line Current	.5 Max. amps
Speed	10000 RPM
Output	.004 H. P.

Continuous Duty .5" oz.
Intermittent Duty 1.0" oz.

TYPICAL CURVE



If you face a DC motor application problem let a Motordyne field engineer assist in the solution. For prompt attention contact either the East or West Coast facilities.

MOTORDYNE INC.
a subsidiary of air marine motors, inc.

2221 BARRY AVENUE
LOS ANGELES, CALIFORNIA

369 BAYVIEW AVENUE
AMITYVILLE, L. I., N. Y.

Investigation of Solid Film Lubricants and Sliding Contacts at Temperatures Above 1000 F
M B Peterson. General Electric Co. Available from Office of Technical Services, US Dept of Commerce, Washington 25, DC. 8½ x 11, 63 pp. $1.50.

ABSTRACTS FROM THE LITERATURE

Low-temperature Pumpability of Experimental Lubricating Fluids

Present-day lubricants and hydraulic fluids for high-performance aircraft are required to operate over increasingly wider ranges of temperature. Extension of the upper temperature limit, which is imperative for operation of these vehicles, causes a severe problem in maintaining low-temperature capabilities of fluids. This paper presents the results of a program conducted to investigate the initial pumpability characteristics of a group of fluids at subzero temperatures. The tests were specificially designed to provide data concerning fluid characteristics after long soak periods at subzero conditions. The investigation was confined to a study of initial flow characteristics and torque requirements rather than a study of equilibrium flow conditions. Esters, silicones, silanes, and mineral oils were included in this program.

"Low Temperature Pumpability of Experimental Lubricating Fluids," L. R. Drane, USAF; Vernice Hopkins, Midwest Research Institute. American Society of Mechanical Engineers, 61-LUBS-10, 29 W 39th St, NY 18.

Hobbing Versus Gear Design

Deals with hobbing and the influence it has on gear design. Discusses some questions a gear designer should ask when he designs a gear.

"Hobbing Versus Gear Design," M. E. Samuelson, Barber-Colman Co. Society of Automotive Engineers Inc, 485 Lexington Ave, NY 17.

Plastic Foams

There are many types of foams and low-density materials which are available commercially or which can be formulated for electronic packaging. The major types are considered in this article. In general, foams are produced by two methods: 1) the formation of gas as part of the chemical reaction in the production of the foam material, and 2) the generation or evolution of a gas which is created by the decomposition of a blowing agent which has been added to the reacting materials. A blowing agent is merely some material which will liberate gas at the reaction temperatures.

Non-foamed low density compounds are usually formulated by the addition of a low density filler to the base resin. Foams discussed are: urethane, polyether urethane, epoxy, phenolic, silicone, polystyrene, and low-density compounds from low-density fillers.

"Foams and Low-Density Compounds," by Charles A. Harper, Materials and Processes Section, Westinghouse Electric Corp, Baltimore. Insulation, May 1961. Lake Publishing Corp, 311 E Park Ave, Libertyville, Ill.

Drafting Standards for Aluminum

The tables in this booklet supersede the tolerance tables included on pages 16-44 of the Third Edition of Drafting Standards -- Aluminum Extruded and Tubular Products, issued by The Aluminum Extruded Products Division of the Aluminum Association in May 1957 (Second Printing October 1958). Some tables have been revised, some expanded and new tables added.

"Drafting Standards Aluminum Extruded and Tubular Products," Aluminum Association, 420 Lexington Ave, New York 17, June 1960, Third Edition.

How Curing Agents Affect Epoxy Resins

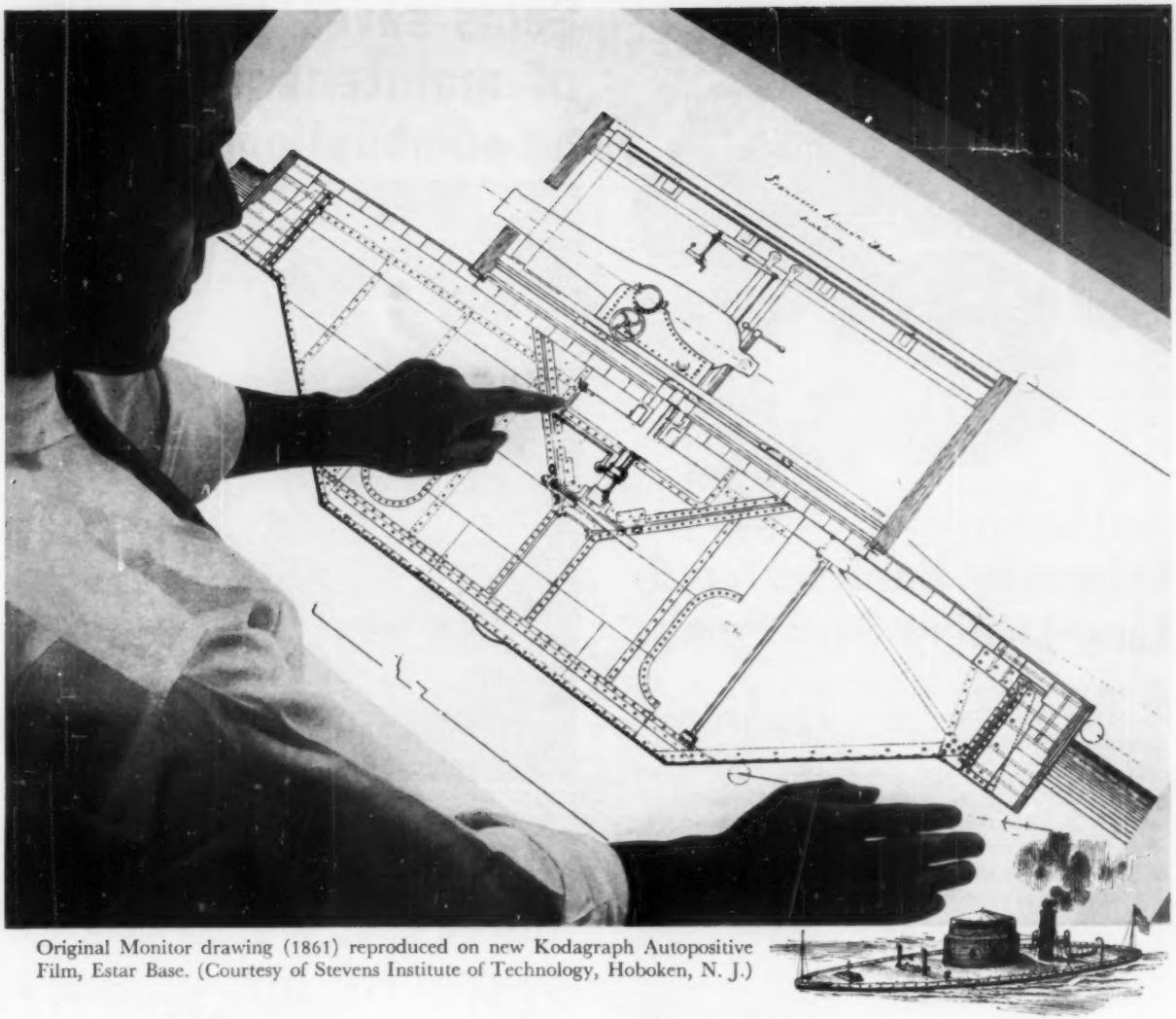
Some seven different epoxy resin systems were exposed to various chemical environments and evaluated for changes in dimensional stability and flexural strengths over a six month period. From the data presented herein, only limited conclusions may be drawn. Heat cured systems fare better than room temperature cured systems in every case. Anhydride cured epoxy resins show greater resistance to outdoor weathering than amine cured systems.

"Effect of Various Curing Agents on the Chemical Stability of Epoxy Resins," by Ronald L. DeHoff, Supervisor of Thermosetting Resins, Shell Chemical Co, Union, NJ, Corrosion, Jan 1961, National Association of Corrosion Engineers, 1061 M & M Building, Houston 2, Texas.

Teflon Bearings

This paper presents some characteristics of PTFE fabric-lined bearings under high bearing loads and slow

continued on page 83



Original Monitor drawing (1861) reproduced on new Kodagraph Autopositive Film, Estar Base. (Courtesy of Stevens Institute of Technology, Hoboken, N. J.)

Made to take the bruises!

New Kodagraph Autopositive Film, Estar Base, gives you intermediates that are as tough as they come and have exceptionally sharp detail.

Here's the ideal choice for general reproduction work and drafting-room use. Same-size, positive intermediates are produced directly without a negative step. And there's the added convenience of being able to expose and process under room light. Excellent results are obtained with either "print-through" or reflex printing, even when reflexing from metal templates.

See this versatile new Kodagraph Film—and the others in the new *Estar Base line:* Kodagraph Contact Film; Kodagraph Projection Film.

All combine reliable Kodak emulsions on the new Estar Base—highly translucent, durable, and dimensionally stable, with excellent matte surface on both sides for easy drafting. Available in standard drawing sheet sizes and in rolls up to 52 inches wide. Call your local Kodagraph Dealer, or write Eastman Kodak Company, Graphic Reproduction Division, Rochester 4, N. Y.

NEW! **Kodagraph**

REPRODUCTION FILMS
for best line-for-line reproduction

Kodak

CIRCLE 81 ON READER SERVICE CARD 81

Gear pump components just before assembly. All parts received Colmonoy hard surfacing in areas subject to wear.

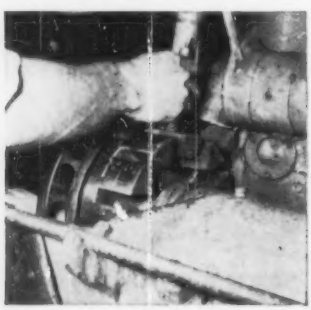
Customers demand . . .

Colmonoy Hard-Surfaced, Long-Lasting Gear Pumps

Pump users know Colmonoy lengthens pump life . . . some manufacturers who know they know it now provide Colmonoy protected parts in new pumps.

Pump components that can be lathe-mounted are easily hard-surfaced with the Colmonoy Spraywelder. A Colmonoy nickel-base alloy Sprayweld* Powder (there are 5 grades) is applied to the wear-areas. The sprayed overlay is fused to the base metal, creating a non-porous, wear resistant surface. Irregularly shaped parts are overlaid with easy-to-apply Colmonoy oxy-acetylene rods of the same alloy grade.

Get expert advice on your particular needs. Call in a Colmonoy sales engineer or write Detroit.



Above: The Colmonoy Sprayweld unit. Left: Colmonoy overlay on pump rotor being finish ground. Below: The Spraywelder Catalog and Colmonoy Manual. Ask for them.

*Registered trade-mark

HARD-SURFACING & BRAZING ALLOYS

WALL COLMONOY CORPORATION

19345 JOHN R STREET • DETROIT 3, MICHIGAN

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82 CIRCLE 82 ON READER SERVICE CARD

Selas saves thousands of maintenance hours on combustion controls

Reevecote synthetic diaphragm goes into place on pressure governor section of Selas Combustion Controller. Reevecote has more than doubled the service life of diaphragms on these units.

with REEVECOTE SYNTHETIC DIAPHRAGMS

By switching from leather to synthetic diaphragms of Reevecote in its Combustion Controllers, the Selas Corporation of America saved thousands of maintenance hours. They also improved the accuracy of these units.

Problem: Originally, leather diaphragms were used in the mixing valve and in the pressure governor of the compressor. These two diaphragms required the most frequent maintenance of all parts in the unit. The leather had a tendency to dry out, stiffen and crack. Accuracy was impaired. The leather required frequent oilings and service life was limited to less than 12 months.

Solution: Selas switched to synthetic diaphragms of Reevecote 7134 and 7028, made by the Vulcan Rubber Products Division of Reeves Brothers, Inc. After 2 years of service, diaphragm maintenance has been practically nil. The Reevecote diaphragms retained their flexibility, did not dry out, required no oiling. Accuracy improved and thousands of maintenance hours were saved.

If *your* design calls for any type of diaphragm – any use of coated fabrics – choose from over 200 styles of Reevecote – the most complete line of synthetic coated fabrics for industry. Write for new Reevecote Catalog.

REEVES VULCAN

Reeves Brothers, Inc., Vulcan Rubber Products Division
1071 Avenue of the Americas • New York 18, New York

CIRCLE 204 ON READER SERVICE CARD

speed oscillation without lubrication.

The effect of load, speed and angle of oscillation on wear life is shown as well as coefficient-of-friction variation with load and ambient temperature.

Optimum shaft finish for sleeve bearings and effect of initial lubrication on wear and friction is presented.

The investigation covers a range of loads from 5800 to 32,500 psi and testing speeds from 5 to 33 cycles per minute.

"PTFE Bearings for High Loads and Slow Oscillation," by W. D. Craig Jr. Mechanical Design Section, Grumman Aircraft Engineering Corporation, Bethpage, Long Island, NY. Presented at the 16th ASLE Annual Meeting Apr '61, Philadelphia.

Corrosion-resistant Alloys

This booklet gives characteristics of various alloys such as stainless steel, aluminum, nickel, copper, and high-temperature resisting materials.

"Harper Alloys," Harper Corrosion Guide, p 7.

CATALOGS AND BULLETINS

To obtain copies of literature described below, circle corresponding number on postcard inside back cover.

SWITCHES—Catalog, 30 pp. Traces electrical ratings, construction, dimensions, operating ranges, etc, of low-pressure, vacuum, differential-pressure, air-flow interlock and water-flow interlock switches; flowmeters; manometers; air filter gages, etc. Photos and dimension drawings are included. Henry G Dietz Co Inc, 12-16 Astoria Blvd, Long Island City 2, NY.

Circle 350 on Reader Service Card

VALVES—Catalog 10-B, 16 pp. Illustrates and outlines specifications of bronze, iron body and cast steel valves, including gate, globe and angle and check units; bar stock valves; and forged steel gate valves. R-P&C Valve Div, American Chain & Cable Co Inc, Reading, Penna.

Circle 351 on Reader Service Card

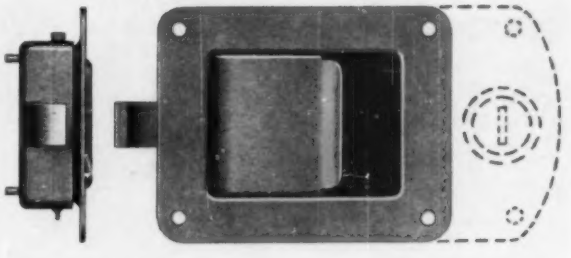
STAINLESS STEEL BALL BEARINGS—Bulletin 1551, 4 pp. Tabulates dimensional details and load ratings of single-row, deep groove radial types. Typical applications are listed. Marlin-Rockwell Corp., Jamestown, NY.

Circle 352 on Reader Service Card

INDUSTRIAL LIMIT SWITCHES—Catalog 201, 12 pp. Reviews different bases, lever styles, ampere ratings, operating data and temp ranges of heavy duty and plug-in types. Forty-five contact ar-

continued on page 85

YOU CAN THINK OF 100 IDEAL PRODUCT APPLICATIONS for The Circle E "4859 LATCH"



A welcome development in a neat, modern-appearing latch with a unique time-tested action. "PADDLE LATCH" incorporates a long proven mechanical action which has met with outstanding acceptance in the automotive hardware field for several years. Its multiple merits can now be put to excellent use in the various O.E.M. fields.
Bright nickel or plain finish. Installed with screws, rivets or by welding. For small doors, electrical panel boards, cabinets, lockers, etc. 2⅜" x 2" Receptacle size. Write for detailed information and specifications.

The EBERHARD MFG. CO.
DIVISION OF THE EASTERN CO.
2701 Tennyson Rd. Cleveland 4, Ohio

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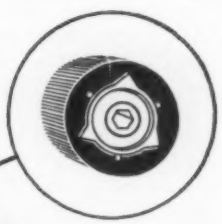
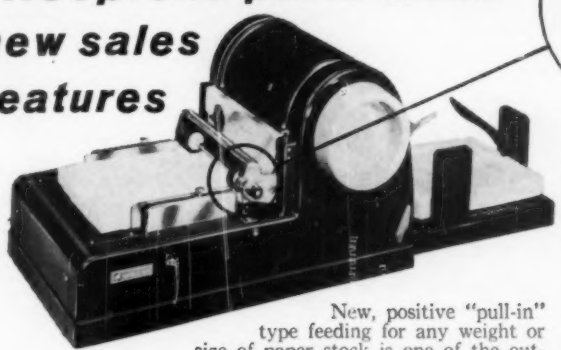
***WILBOW* molded Neoprene parts mean new sales features**





Corrugated Neoprene feed rolls by WILBOW assure positive single-sheet feeding.

New, positive "pull-in" type feeding for any weight or size of paper stock is one of the outstanding performance features of the recently introduced *Liberator 600* Duplicator by Speed-O-Print Corporation. To produce the specially engineered feed rolls required, with precisely controlled characteristics of size, yield, texture and wear resistance, Speed-O-Print called on WILBOW.

WILBOW excels in the manufacture of high-performance, high-precision mechanical rubber parts to meet the most exacting requirements. A full range of synthetic, natural or silicone polymers . . . plus complete equipment for molding, lathe cutting, die-cutting or extruding . . . is at your service to make the parts that will give your product new sales appeal. Why not check the possibilities with WILBOW today?

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The WILLIAMS-BOWMAN RUBBER CO.
1955 South 54th Avenue • Cicero 50, Illinois • (Chicago Suburb)
Mfrs. of molded, punched, extruded and cut rubber goods. Specialists in producing rubber covered rolls, silicone rubber parts and bonding rubber to metal

CIRCLE 83 ON READER SERVICE CARD

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If you're looking for prototype precision in quantity production with immediate delivery schedules, you just can't beat DYNACO Precision Stock Gears and Assemblies, engineered to answer every conceivable transmission requirement.

More than 50,000 different off-the-shelf gears and components are listed in Dynamic's Catalog F-128. Send for your copy today.

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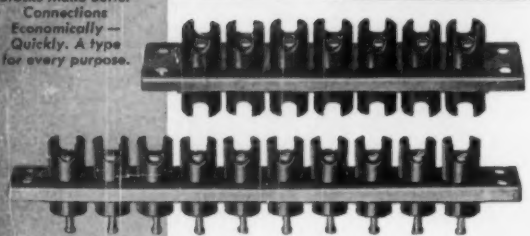
CIRCLE 206 ON READER SERVICE CARD

The Simplest "Feed-Thru" Block Built Today

CURTIS "FT" and "FTS" "Feed-Thru" Terminal Blocks

Curtis Terminal Blocks Make Better Connections Economically — Quickly. A type for every purpose.



Sturdy in construction, simple in design, Curtis "FT" and "FTS" Blocks are the ideal solution for sub-panel and chassis construction where the "Feed-Thru" function is required.

They are built with external screw connection and either screw or solder pin internal connections. The individual phenolic terminals are permanently mounted in strong steel mounting channels of one to 16 terminals, rated 20 amps. at 300 volts.

Simplify your "Feed-Thru" connections with time-saving Curtis "FT" and "FTS" Terminal Blocks.

Write for Bulletins DS111 and DS115. Ask about the wide selection of other Curtis Blocks available.

CURTIS DEVELOPMENT & MFG. CO.

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Adaptable Drafting Furniture!

METAL PLAN FILE

Mayline 5-Drawer Metal Plan Files can be attached to Mayline steel 4-Post drafting tables. A file mounted on a table gives 5 drawers of filing space.

The 4-Post steel table offers 6 combinations of drawer and filing units. You have a choice in drawing tops of either solid basswood or linoleum covered steel.

For complete details on both products ask your dealer for folders S-20 and S-21.

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rangements are shown, together with descriptions and wiring diagrams. R B Denison Mfg Co, 386 Broadway, Bedford, Ohio.

Circle 353 on Reader Service Card

INDUSTRIAL FELTS—Catalog, 16 pp. Alphabetically lists hundreds of applications with proper type felt to use. Data on roll and sheet felts include comparative price coefficients, fabricating methods, and physical, mechanical and chemical properties. Continental Felt Co, 22 W 15th St, New York 11.

Circle 354 on Reader Service Card

LOGIC CIRCUIT PLUG-INS—Bulletin 60-D, 4 pp. Summarizes specifications of high-speed digital logic circuit plug-ins, including gates, flip-flops, inverters, amplifiers and pulse generators. Points out 5-megacycle data rates, loading rules and construction of the transistor-equipped modules. Circuit diagrams are included. Rese Engineering Inc, A & Courtland Sts, Philadelphia 20.

Circle 355 on Reader Service Card

TEXTURED STEEL—Handbook, 20 pp. Covers sizes, designs, actual and suggested product uses and methods of fabricating surface-rolled patterns in stainless, carbon and coated steels. Over 50 patterns are pictured. Sharon Steel Corp, Sharon, Penna.

Circle 356 on Reader Service Card

PERMANENT - MAGNET ASSEMBLIES—Bulletin, 3 pp. Describes, illustrates and gives prices of ceramic magnets with designed-in mild steel pole pieces. Bryan Mfg Co, 202 Manning St, Needham Heights 94, Mass.

Circle 357 on Reader Service Card

SELF-ALIGNING LOCKNUT—Folder 2724, 6 pp. Diagrams illustrate action of two-part nut which eliminates bending of bolts in cases of surface misalignment. Describes effect of bending on bolt fatigue life and lists specifications of 160,000-psi-tensile-strength nut. Standard Pressed Steel Co, Box 545, Jenkintown, Penna.

Circle 358 on Reader Service Card

INDICATING LOAD CELL SYSTEMS—Bulletin R-2, 12 pp. Covers tension, tensile and push-pull models in 33 capacities from 0-100 through 0-1,000,000 lb. Discusses performance features, tabulates dimensions and compares differential transformer principle with conventional tube and circuitry designs. W C Dillon & Co Inc, 14620 Keswick St, Van Nuys, Calif.

Circle 359 on Reader Service Card

BELTING FABRICS—Bulletin, 12 pp. Compares physical properties of typical high-strength rayon and conventional cotton belting fabrics, including weight, warp and filling crimp, grab strength, and conditioned and wet strength factors. Min tensile specifications and fatigue results of the two constructions also are given. Performance curves are included. Industrial Merchandising Div, American Viscose Corp, 350 5th Ave, New York 1.

Circle 360 on Reader Service Card

PRECISION ORIFICES—Catalog, 4 pp. Contains installation diagrams and describes design features of units for restricting and regulating fluid flow. Lee Co, Westbrook, Conn.

Circle 361 on Reader Service Card

PIPE, TUBING & WELDING FITTINGS—Catalog, 4 pp. Lists size ranges, performance characteristics and distributors of large diameter stainless steel pipe, tubing and welding fittings. Swepco Tube Corp, 1 Clifton Blvd, Clifton, NJ.

Circle 362 on Reader Service Card

SPECIAL-APPLICATION PUMPS—Bulletin 150.4, 4 pp. Tabulates ratings of 16 available sizes when operated at various speeds and discharge pressures. Also contains dimension drawings, parts list and discussion of rotor-stator "pregressing cavity" principle for handling abrasives or suspended solids without damage. Moyno Pump Div, Robbins & Myers Inc, Springfield, Ohio.

Circle 363 on Reader Service Card

MACHINE MOUNTS—Catalog 4011, 4 pp. Supplies, sizes and capacities available. Includes curves showing physical properties of mounting pad materials. Clark-Cutler-McDermott Co, Franklin, Mass.

Circle 364 on Reader Service Card

TRANSDUCERS, PRESSURE INSTRUMENTS—Six bulletins, 2 pp. each. Covered are digital transducers, miniature and subminiature potentiometer pressure transducers, subminiature pressure switches, subminiature electrovisual pressure transducers and miniature high pressure transducers. Each bulletin contains design features, performance characteristics and outline drawings. Electronics Div, DeJur-Amsco Corp, 45-01 Northern Blvd, Long Island City 1, NY.

Circle 365 on Reader Service Card

PRESSURE TRANSDUCER—Bulletin 4350, 2 pp. Carries design features, as well as input, output, environmental and physical specifications. Wiring diagram and outline drawings are included. Consolidated Electrodynamics Corp, Sub of Bell & Howell Co, 360 Sierra Madre Villa, Pasadena, Calif.

Circle 366 on Reader Service Card

STAINLESS STEEL MACHINING—8½ x 11-in. chart. Provides table of recommended machining rates for 37 types of stainless steel. Includes sfm to rpm conversion table. Peter A Frasse & Co Inc, 17 Grand St, New York 13.

Circle 367 on Reader Service Card

LIGHT-INDICATOR MODULES—Folder, 4 pp. Contains photos, schematics and summary of general characteristics, power requirements, color intensity, type of trigger signal needed, life expectancy, etc. Covered are neon glow and incandescent lamps with transistor amplifiers, and filamentary and cold cathode thyratrons. Raytheon Co, Industrial Components Div, 55 Chapel St, Newton 58, Mass.

Circle 368 on Reader Service Card

ELECTRIC PREDETERMINING COUNTERS—Bulletin 227845-2500, 2 pp. Supplies complete specifications, including counting speed, front panel elements, weight and electrical data. Applications are indicated, and design features listed. Includes outline drawings. Veeder-Root Inc, Electronic Controls Div, Danvers, Mass.

Circle 369 on Reader Service Card

DIRECT-RECORDING CAMERA—Pamphlet, 4 pp. Describes and illustrates design and performance features of unit for recording oscilloscope traces. Shows typical waveforms recorded by unit and lists accessories. Tektronix Inc, PO Box 500, Beaverton, Ore.

Circle 370 on Reader Service Card

"Mr. Glibley puzzles me. Today he called me 'his little coefficient of expansion'!"

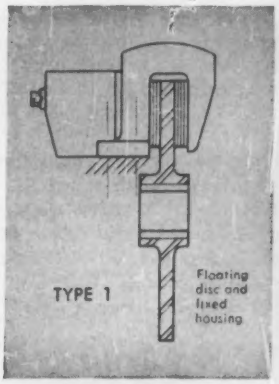
FOR MORE CATALOGS AND BULLETINS

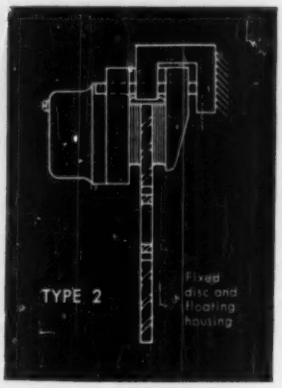
. . . 1600 of 'em—see your copy of Product Engineering's Mid-Sep 1960 Design Digest. There you will find helpful design literature, classified under 10 different headings, from important manufacturers and suppliers of components, materials, power and local systems, manufacturing processes.

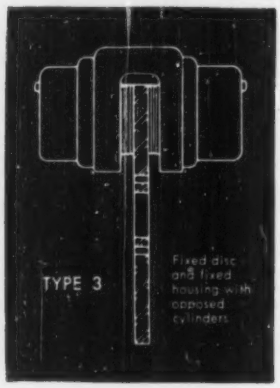
one of these

disc brakes

can solve your tough problem!







Look at these Goodyear disc brake features: **Equal torque** in either direction—**Fast cooling,** with high kinetic energy capacity — **Flexible operation** — hydraulic, pneumatic or mechanical — **Automatic adjustment** for lining wear (with hydraulic and air units)—**Easy lining replacement** cuts down time.

Goodyear disc brakes are now stopping:

Mining equipment—shuttle cars, loading machines, continuous miners.

Materials-handling equipment—lift trucks, earth-movers, power shovels.

Aircraft equipment—crash trucks, arresting gear, helicopter rotors *plus* ski lifts, amphibious military vehicles and mobile trailers.

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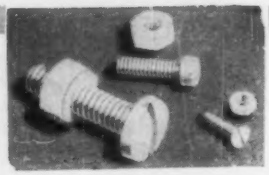

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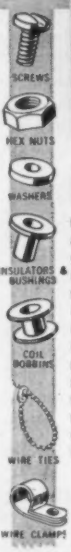

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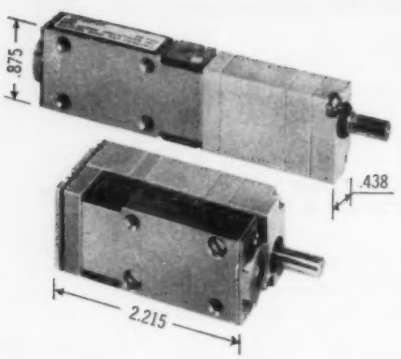

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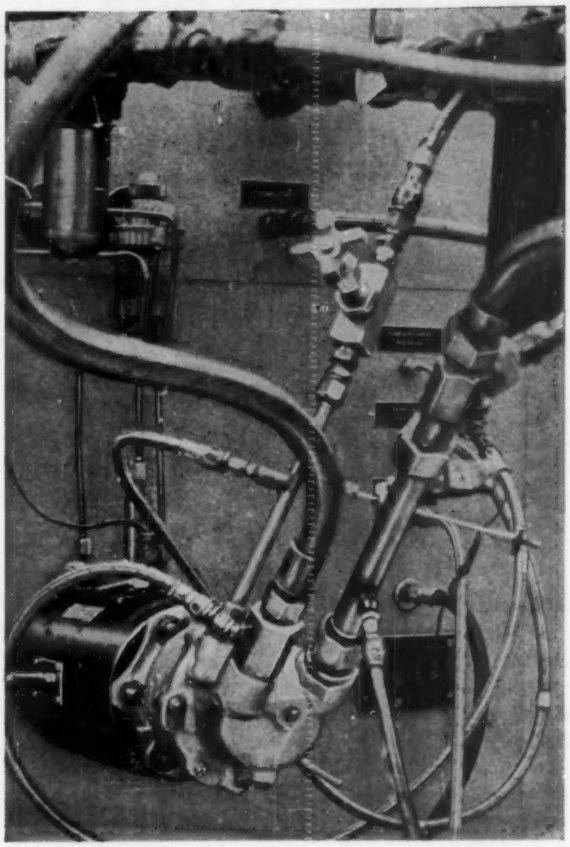

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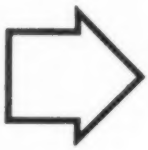

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11	31	51	71	91	111	131	151	171	191	211	231	251	271	291	311	326	341	356	371	386
12	32	52	72	92	112	132	152	172	192	212	232	252	272	292	312	327	342	357	372	387
13	33	53	73	93	113	133	153	173	193	213	233	253	273	293	313	328	343	358	373	388
14	34	54	74	94	114	134	154	174	194	214	234	254	274	294	314	329	344	359	374	389
15	35	55	75	95	115	135	155	175	195	215	235	255	275	295	315	330	345	360	375	390
16	36	56	76	96	116	136	156	176	196	216	236	256	276	296						
17	37	57	77	97	117	137	157	177	197	217	237	257	277	297						
18	38	58	78	98	118	138	158	178	198	218	238	258	278	298						
19	39	59	79	99	119	139	159	179	199	219	239	259	279	299						
20	40	60	80	100	120	140	160	180	200	220	240	260	280	300						

REPRINTS

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603	604	605	606	607	608	609	610	611	612	613	614	

*MULTIPLE Key No.	PRODUCT ADS Specific Product

(please print or type) *If this is change of address, check box* ☐

Name..... Title.....

Street.....

City..... Zone..... State.....

Company..... Major Product Manufactured.....

1	21	41	61	81	101	121	141	161	181	201	221	241	261	281	301	316	331	346	361	376
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9	29	49	69	89	109	129	149	169	189	209	229	249	269	289	309	324	339	354	369	384
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REPRINTS

591	592	593	594	595	596	597	598	599	600	601	602	
603	604	605	606	607	608	609	610	611	612	613	614	

*MULTIPLE Key No.	PRODUCT ADS Specific Product

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Issue of June 26, 1961
PRODUCT ENGINEERING
Card Expires August 25, 1961

FIRST CLASS
PERMIT No. 64
NEW YORK, N. Y.

BUSINESS REPLY MAIL
No Postage Stamp Necessary If Mailed in the United States

Postage Will Be Paid By Reader Service Department

Inquiries Services Department
PRODUCT ENGINEERING
P.O. Box 601
Ridgefield, Connecticut

2

Issue of June 26, 1961
PRODUCT ENGINEERING
Card Expires August 25, 1961

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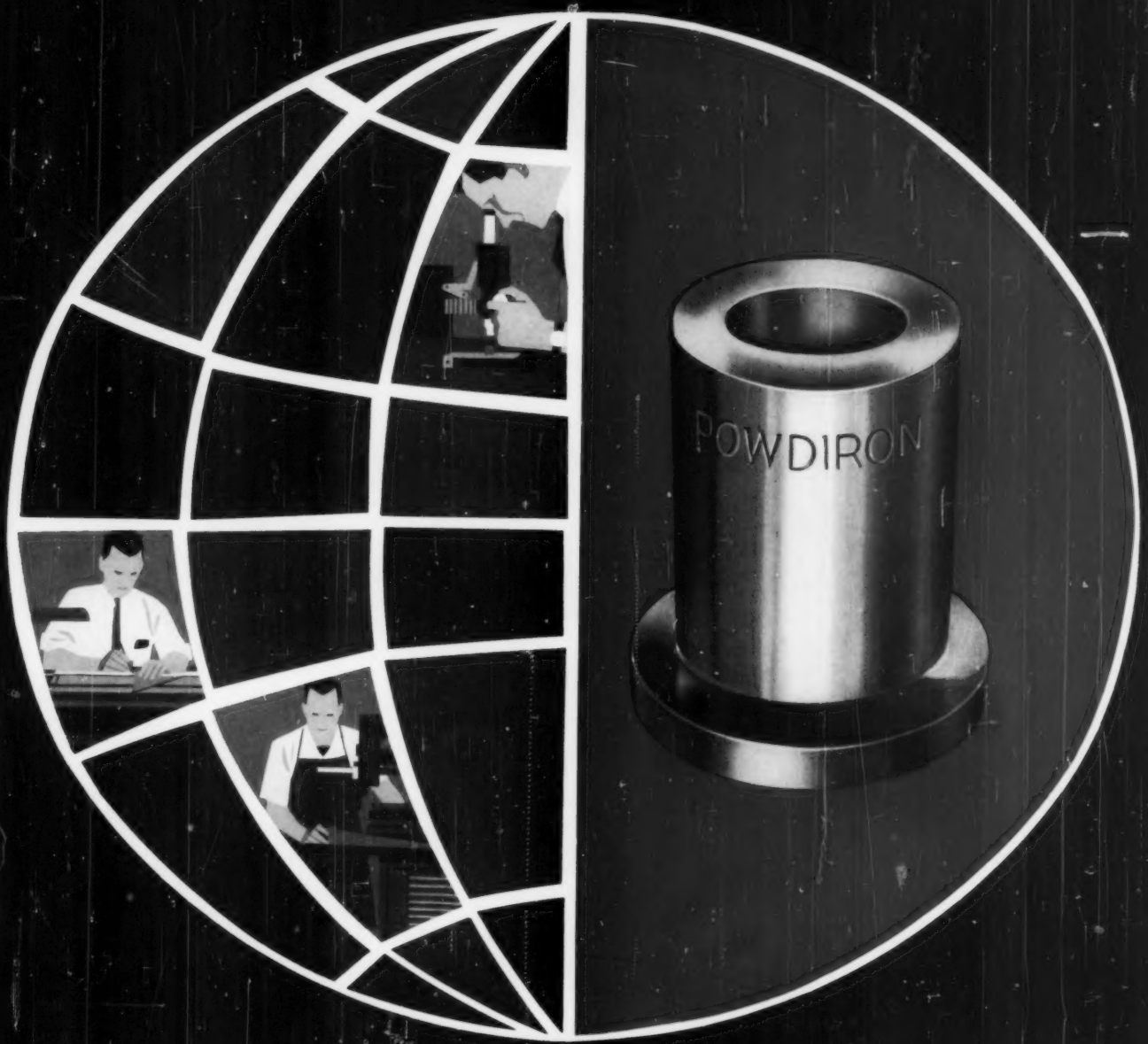
1



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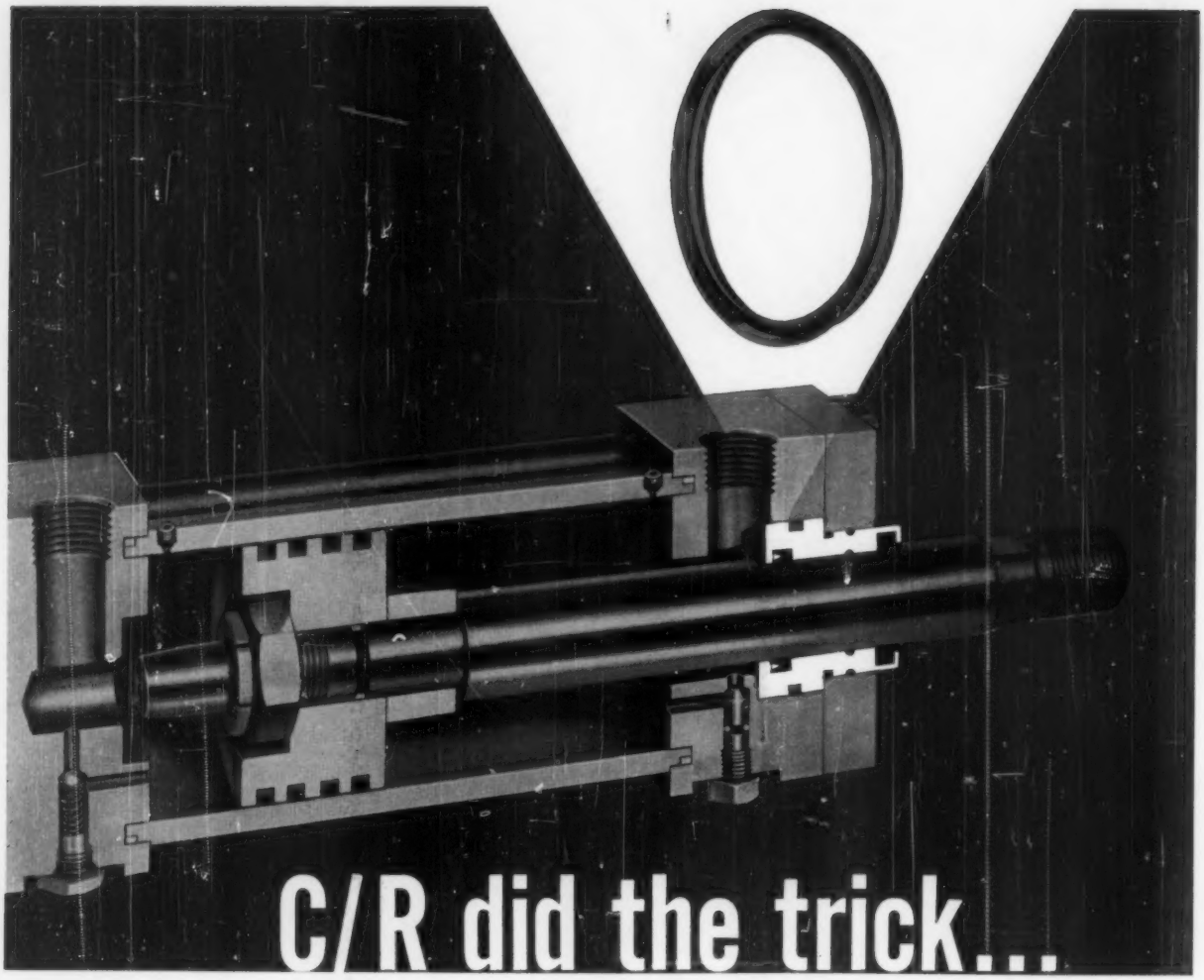
From Bound Brook's newly-formed association with the world-wide organization of Birfield Limited, comes the new Ferrocite process—making possible economies of operation never before available in self-lubricated iron bearings of Bound Brook quality. The high standards of Powdiron® quality have been retained, but the resultant economies make Bound Brook your best buy in iron bearings. The next time your specs call for self-lubricated iron bearings, it will pay you to call Bound Brook.

BOUND BROOK BEARING
CORPORATION OF AMERICA
A BIRFIELD COMPANY
Pioneer in Powder Metallurgy Bearings and Parts • Plants at Bound Brook, N.J. and Sturgis, Mich.



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Specially compounded and molded parts gave this manufacturer the competitive edge he wanted!

Hydro-Line Manufacturing Company posed this problem to C/R: produce an elastomer rod seal and dirt seal with the highest possible resistance to wear (equal or superior to Buna-N) — that will function dependably in air at temperatures ranging from –40° to 450° F. Further, the seals must be compatible with the widest range of industrial hydraulic fluids.

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C/R† can do the same for you. We have the special techniques, knowledge and facilities to help you give your product a competitive advantage. Call or write for immediate information or engineering assistance.

†T.M. Reg. U.S. Pat. Off.

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SIRVENE DIVISION, 1237 ELSTON AVENUE • CHICAGO 22, ILLINOIS

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In Canada: Chicago Rawhide Mfg. Co., Canada, Ltd., Brantford, Ontario

Export Sales: Geon International Corp., Great Neck, New York

C/R PRODUCTS: C/R Shaft & End Face Seals • Sirvis-Conpor mechanical leather cups, packings, boots • C/R Non-metallic gears

C/R®

CIRCLE 203 ON READER SERVICE CARD